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THE EFFECTS OF R&D TAX INCENTIVES AND THEIR ROLE IN THE INNOVATION POLICY MIX

FINDINGS FROM THE OECD MICROBERD PROJECT, 2016-19

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The effects of R&D tax incentives and their role in the innovation policy mix – findings from the OECD microBeRD project, 2016-19

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This report presents new evidence on the impact of R&D tax incentives and direct funding of business R&D, drawing on distributed cross-country and firm-level analyses undertaken as part of the first phase of the OECD microBeRD project (2016-19). This "distributed" approach facilitates a harmonised analysis of confidential business R&D and tax relief microdata in 20 OECD countries. microBeRD provides new insights into the effectiveness of R&D tax incentives in encouraging business R&D in the OECD area and the heterogeneity of effects both within and across OECD countries, including the underlying impact mechanisms. The report contributes to the debate on the role of R&D tax incentives in the policy mix by providing additional comparative evidence on the effects of alternative business R&D inducement incentives.

Keywords: Science and technology, Tax, Innovation

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Due to the outbreak of the COVID-19 pandemic, the last round of distributed analysis could not be fully completed in time before publication for all participating countries. As a result, outputs calculated within the United States and additional firm-level regression results for Canada and the United Kingdom could not be incorporated in this report. Such results are expected to feature in further microBeRD reports produced as part of the next phase of the microBeRD project (microBeRD+).

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Executive Summary

Research and development (R&D) is an important driver of innovation and economic growth, but the existence of knowledge spillovers coupled with financing difficulties may make firms invest less in R&D than what would be socially optimal. To encourage demand driven business R&D investment, governments worldwide make use of various policy instruments to incentivise R&D performance. In addition to R&D grants and purchases of R&D services ("direct support"), many governments use the tax system as an additional inducement mechanism. These preferential tax provisions may relate to R&D inputs (expenditures) or outputs (incomes from licensing or asset disposal attributable to R&D or patents).

Over the last decade, expenditure-based R&D tax incentives have become a major business innovation support policy tool in OECD countries and partner economies. In 2017, R&D tax incentives accounted for around 50% of total government support for business R&D in the OECD area, up from 30% in 2000. The proliferation of R&D tax incentives raises important policy questions about the effectiveness of different policy tools in stimulating R&D, the heterogeneity of effects across different types of firms and the interaction of different policies.

The OECD microBeRD project investigates the structure, distribution and concentration of business R&D and R&D funding and models the incidence and impact of public support for business R&D. **microBeRD applies a "distributed" approach** to the analysis of business R&D and tax relief microdata, adopting a "hybrid" approach that combines the benefits of studies conducted at the macro level (e.g. generalisability) and at the micro level (e.g. ability to explore heterogeneous effects across firms). For example, many aggregate trends appear to be mostly accounted for by the behaviour of a smaller group of large enterprises, hiding relevant dynamics among SMEs.

This report presents the impact assessment oriented results from the **first phase of the microBeRD project (2016-2019)**. The report focuses on **R&D input additionality**, i.e. the effectiveness of R&D support policies in encouraging additional business R&D investment compared to a counterfactual scenario in which no support is provided. While the main part of the analysis focuses on the impact of R&D tax incentives, the report also examines, on an exploratory basis, the role of corporate income taxation and direct funding of business R&D.

The impact analysis has two components:

- **A cross-country analysis based on pooled, non-disclosive micro-aggregated data for 20 OECD countries over the 2000-17 period** estimates the elasticity of business R&D expenditure and other R&D related outcomes to changes in the user cost of R&D – measured by the *B-Index.*
- **Country-specific analyses based on firm-level data** involve regressions run in a distributed way directly on the national microdata, separately within each country but following a harmonised methodology.

Both types of impact analysis generate estimates of the "incrementality ratio" for tax and direct support measures. This ratio, a measure of R&D input additionality, specifies the amount of R&D induced by one monetary unit of public funding (commonly referred to as "bang for the buck"). Incrementality ratios represent an important input to cost-benefit analyses as indicators of effectiveness, but they are not sufficient to make claims on whether the benefits of business innovation policies outweigh their costs. The analyses presented in this report are intended to enhance the existing evidence on the impact of government support for BERD; they are not intended to evaluate national policies.

The key findings from the microBeRD analysis can be summed up as follows:

- **General effect on R&D expenditures:** The cross-country micro-aggregated impact analysis (accounting for the fact that not all R&D performing firms actually receive R&D tax relief) yields a gross incrementality ratio (IR) of around 1.4 (one extra unit of R&D tax support translates into 1.4 extra units of R&D). The effect on experimental development is about twice as large as the effect on basic and applied research.
- **Impact mechanisms**: R&D tax incentives not only increase expenditures but also the level of human resources that firms report to dedicate to R&D. They do not appear to affect R&D unit labour costs, suggesting that the effects of tax incentives are not absorbed into higher wages. Furthermore, R&D tax incentives encourage additional business R&D both because existing R&D performers increase their R&D expenditure (intensive margin) and because additional firms start performing R&D (extensive margin).
- **Heterogeneity of business response**: The input additionality of R&D tax incentives is larger for small (IR: 1.4) and medium-sized (IR: 1.0) firms vis-à-vis large companies (IR: 0.4). This is a reflection of the fact that smaller firms perform, on average, less R&D than larger firms, rather than of economic size as such. In a similar vein, little input additionality (IR: 0.3) is found for firms in highly R&D-intensive industries (Pharmaceuticals, Computer manufacturing, Scientific R&D).
- **Policy mix:** The exploratory analysis indicates a similar degree of input additionality for direct R&D government funding measures (IR: 1.4) compared to tax incentives and hints at the potential complementarity of direct and indirect support measures. Direct support measures appear more conducive towards promoting research whereas tax support is principally associated with heightened levels of experimental development. Additionally, a lower level of corporate income taxation is also associated with more R&D investment, although with a lower incrementality ratio than the more targeted R&D support policy measures. One unit of foregone tax revenue corresponds to a 0.24 unit increase in business R&D expenditure.
- **Country-specific effects:** Firm-level estimates of the effect of tax incentives and direct funding are consistent with the average effects found in the micro-aggregated analysis, but they also highlight a substantial heterogeneity in input additionality across countries. This is in part related to differences in the uptake and distribution of indirect and direct support measures across different types of firms, underscoring a need for a systematic examination of the link between business innovation policy uptake, design and policy outcomes.

Chapter 1. Introduction

Governments worldwide seek to encourage firms to invest in R&D and create new knowledge that can result in innovations that transform markets and industries and result in benefits to society. Business play a major role as R&D performers in most market economies, around 70% of the total R&D in OECD economies is performed within private or public enterprises. However, this is only to some extent possible due to a combination of policies and interventions. Government become active actors in the provision of R&D through the creation, oversight and funding of entities that specialise in the creation of knowledge that would be otherwise difficult or impossible for private entities to produce. All industries rely extensively on fundamental science and ideas originating from or developed within the government sector itself or publicly-funded institutions, but support of a financial nature is also provided for a number of reasons.

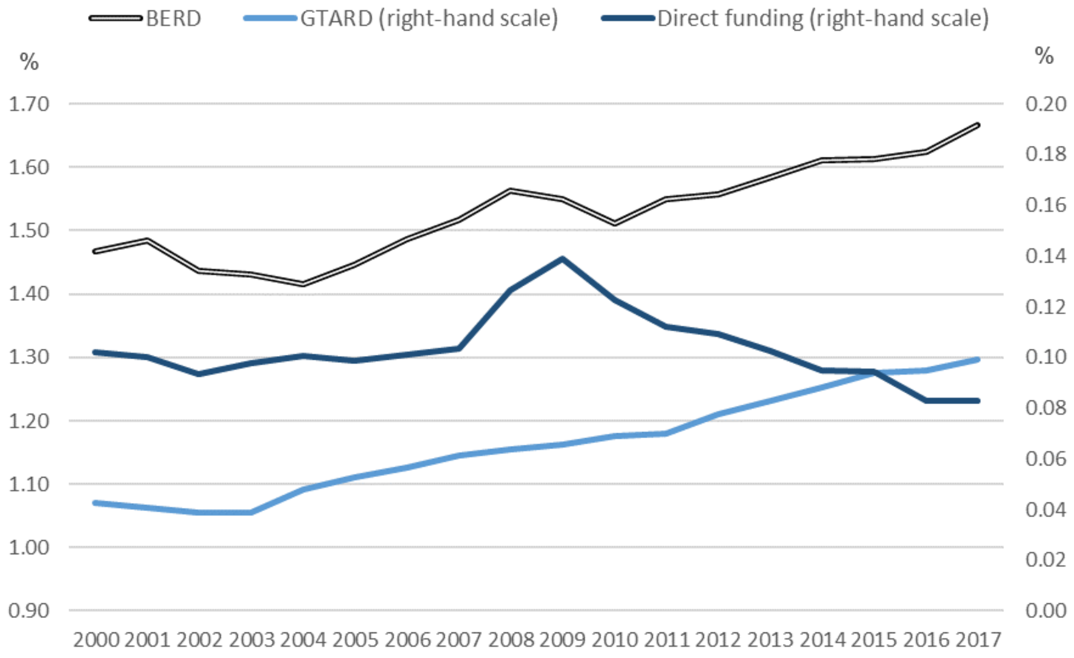
Most often, financial support is provided to firms with the intention of correcting or alleviating difficulties to appropriate the returns to their investment in new knowledge and shortcomings in the market for the financing of risky projects, especially for small start-up firms without collateral. The presence of positive externalities from R&D and financial constraints make firms invest in R&D less than would be socially optimal. Several studies have found social economic returns to R&D (returns to the entire economy) to be substantially larger than private returns (returns to the investing firm).[1]

Governments combine various financial support instruments to counteract these market failures and induce companies to sustain or increase their R&D spending. One major class of instruments focus on supporting the inputs of the R&D activity.[2] This might be for example in the form of payments for R&D services rendered to government entities, who acts as customers, or unconditional payments such as grants, where the condition for support is the conduct of R&D projects over which the firm has complete control. These direct forms of funding can also be complemented by indirect support mechanisms that are still linked to the R&D activity of firms but contingent on other elements, as in the case of tax relief for R&D expenditures where the support received can depend on the firm's tax liability.[3] Over the last decade, expenditure-based R&D tax incentives, have emerged as the primary R&D support tool in many OECD countries (Appelt et al., 2016). In 2019, 30 of the 36 OECD countries offer R&D tax incentives, up from 19 OECD countries in 2000.

To provide a more complete picture of governments' efforts to incentivise business R&D, the OECD Directorate for Science Technology and Innovation has collected – via its Working Party of National Experts on Science and Technology Indicators (NESTI) - information on both the design and cost of R&D tax incentives on a systematic basis since 2007. This data collection effort has facilitated the development of the OECD R&D tax incentive database (OECD, 2019a) with the first curated time-series of estimates of government tax relief for R&D (GTARD) and implied marginal R&D tax subsidy rates based on the B-Index. **Figure 1** displays the evolution of business expenditure on R&D (BERD), GTARD and direct government support for BERD in OECD countries. In 2017, R&D tax incentive support accounted for 0.1% of GDP, while direct funding of BERD amounts to 0.08% of GDP. This implies, that 55% of all government support for R&D in the OECD area was provided through tax incentives, up from 30% in 2000.

Figure 1. Trends in BERD and government tax and direct support for BERD, 2000-17

As percentage of GDP, OECD countries (weighted average)



Note: This chart displays figures for 36 OECD countries, excluding Colombia where relevant direct funding figures are not available. GTARD figures exclude Israel where relevant data are not available. Direct support estimates include government R&D grants and public procurement of R&D services, but exclude loans and other financial instruments that are expected to be repaid in full.
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, June 2020.

These data collection efforts have also set the stage for the launch of the OECD microBeRD project in 2016 - a joint CSTP-CIIE project, undertaken under the auspices of NESTI. microBeRD investigates the structure, distribution and concentration of business R&D and sources of R&D funding across countries and models the incidence and impact of public support for business R&D. For R&D tax incentive and business innovation policies more generally, to achieve their objectives in the most efficient fashion, policy makers need to understand how effective the various policy tools are in stimulating R&D, the heterogeneity of effects across different types of firms and the interaction of policies.

This report presents the results from the microdata based impact analysis undertaken in the first phase of the microBeRD project (2016-2019). This analysis focusses on the effectiveness of government support in promoting additional business R&D (R&D input additionality). microBeRD adopts a novel ("hybrid") approach in assessing the impact of public support. This approach combines some of the advantages of cross-country studies (e.g. generalisability, rich cross-country variation in the R&D support policy mix and R&D tax incentive design), for example those based on country or industry-level data, with the strengths of country-specific studies undertaken at the level of the firm (e.g. the ability to explore the heterogeneity of effects across different types of firms and impact mechanisms). It is based on a distributed microdata analysis approach, that relies on the collaboration between OECD and national experts with access to relevant micro data in participating countries who apply harmonised cleaning, statistical and estimation routines on representative firm-level data on R&D performing firms. This harmonised methodology facilitates the cross-country comparability of results.

The microdata based analysis comprises two elements: (1) a cross-country impact analysis based on pooled micro-aggregated data for 20 OECD countries; and (2) within-country firm-level regression analyses. The micro-aggregated impact analysis investigates the link between user cost of R&D (through the *B-Index*) and business R&D expenditure at the level of groups of firms in the same country, industry and size class, whereas the firm-level analyses explore the effect of R&D tax incentives and direct funding of BERD at the level of individual firms. Firm-level estimates of the effects of tax incentives (direct funding) are reported for 10 (10) countries. These microdata-based outputs which, designed and checked to be non-disclosive, do not present a confidentiality problem.

The main results of this report come in the form of "incrementality ratios", which measure the amount of R&D induced by one dollar of public funding (commonly referred to as "bang for the buck"). These ratios represent a common measure of R&D input additionality and have the advantage that they are, in principle, comparable across countries and across policy instruments. Incrementality ratios represent an important input to cost-benefit analyses, but alone they are not sufficient to make claims on whether the benefits of business innovation policies outweigh their costs. The analyses presented in this report are not intended to *evaluate* national policies or be a substitute for national evaluations.

Instead, these analyses aim to complement existing, ongoing or planned evaluations at national level by taking a broader, international perspective and improving the existing evidence. This report includes evidence on the effectiveness of R&D tax incentives in inducing additional R&D investment by business, distinguishing between different types of R&D inputs (labour, other current, capital, subcontracted R&D), and the orientation of R&D investment (research vs. development). It provides new insights into the underlying impact mechanisms (e.g. price vs. quantity effects), and heterogeneity of effects across different types of firms (e.g. by firm size, industry). While the main part of the analysis focuses on the impact of R&D tax incentives, this work also examines, on an exploratory basis, the effect of other policy instruments – the level of corporate income taxation and direct funding of business R&D– and their interaction with R&D tax incentives.

The remainder of the report is structured as follows. **Section 2** introduces the distributed approach to microdata analysis, describes the R&D microdata used within the microBeRD project and summarises the micro-aggregated indicators generated through the microBeRD distributed code. **Section 3** presents the methodology and results of the analysis based on micro-aggregated data. This is followed by **Section 4**, which describes the firm-level analysis carried out across countries and explains the main results. **Section 5** concludes by summarising the main findings of the report, focusing on their practical significance for policy makers, and points out potential avenues for future work.

Chapter 2. The distributed microBeRD approach explained

In recent years, the policy and research communities' interest in the use of harmonised cross-country business microdata has increased significantly. This has been partly driven by improvements in computing power and storage capacity but, fundamentally, reflects the recognition that microdata are needed for understanding the growing complexity in the way economies work and the heterogeneity in economic outcomes. Significant access obstacles remain, however, that prevent the transnational use of official microdata. As a result, and with few exceptions, cross-country studies based on the analysis of official business microdata are rare, particularly in the area of science, technology and innovation.

The microBeRD project adopts a distributed approach towards the analysis of business R&D microdata, characterised by a collaboration between the OECD secretariat and national experts with access to the confidential R&D and public support microdata. This unique arrangement allows the implementation of a common and centrally-developed code which provides the basis for the harmonised analysis of cross-country microdata while respecting access conditions to nationally held, confidential business microdata.

This section introduces the distributed approach of the microBeRD project, describes the microdata sources used in the distributed analysis, its operation and the nature of resulting outputs.

2.1. Distributed microdata analysis

The distributed microdata analysis is a method of analysing microdata held in separate enclaves by means of a common, centrally designed routine. This routine is automated and flexible enough to run on different data sources in different countries and take into account some of their idiosyncrasies. It relies on the collaboration of an international network of national experts, with each national team having legal access to their respective national microdata. The use of harmonised cleaning, statistical and estimation routines ensures the generation of harmonised, microdata-based outputs which, designed and checked to be non-disclosive, do not present a confidentiality problem. Examples include the custom production of summary statistics for the relevant population and subgroups, as well as other statistics such as statistical inference indicators, for example, regression coefficients and related measures of precision.

The harmonisation procedures ensure that sample composition (e.g. coverage of firm size classes and industries)[4] and methodological choices will be identical or at least mutually consistent, thus raising the cross-country comparability of results.

The generic microdata approach for the analysis of business data was pioneered in the beginning of the 2000s in a series of cross-country projects on firm demographics and productivity (Bartelsman, Scarpetta, et al., 2005; Bartelsman, Haltiwanger, et al., 2009). Over recent years, the OECD has built expertise in implementing distributed microdata approach through the Innovation in firms project (OECD, 2009) on business innovation microdata, the DynEmp (Criscuolo et al., 2014) and MultiProd (Berlingieri et al., 2017) projects.[5] The use of organisational microdata is recommended in both the Frascati and Oslo Manuals (OECD, 2015 and OECD/Eurostat, 2018), especially in the latter which outlines the possible use of distributed approaches to examine the impact of R&D and innovation policies, as presented in this document.

Building on the experience and statistical code developed in earlier OECD projects, the microBeRD project applies the distributed approach to the impact analysis of public support for business R&D. The distributed approach combines some of the advantages of cross-country studies, for example those based on country or industry-level data with the strengths of country-specific studies undertaken at the level of the firm. Desirable features of the former include its generalisability and possibility to exploit the rich cross-country variation in the mix of R&D support and design of R&D tax incentives. The latter bring the ability to examine the heterogeneity of effects by firm characteristics and the underlying mechanisms. The microdata approach thus represents a second-best solution to the analysis of pooled national microdata. Such an analysis, while not possible at present under current arrangements, would provide more comprehensive insights into the link between R&D support policies and business R&D performance – an increasingly globalised activity – and in particular, the role of MNEs compared to stand-alone domestic firms.

Furthermore, the harmonised approach also ensures that differences in firm-level regression results across different settings are more likely to reflect actual differences in policy design and the type of firms targeted rather than differences in data and methodology, as is often the case when comparing firm-level estimates across independent studies. The distributed method, ensuring a high degree of cross-country harmonisation and comparability, also renders considerable benefits to aggregate R&D data producers and users as it provides an additional and highly complementary source of validation and data quality assessment. Compared to issuing generic requests for indicators from countries, this approach places a lower burden on national statistical agencies and limits the running costs of data collection endeavours. Moreover, it highlights hitherto unidentified cross-country differences in data coverage (e.g. firm age and ownership) and methodology which can help spur further harmonisation and statistical development. For example, microBeRD has been particularly useful in exploring avenues for implementing the recommendations in the latest edition of the OECD Frascati Manual (OECD, 2015) on key areas of public support for R&D and R&D globalisation. The use of a distributed approach in the analysis of R&D statistics has also contributed to promote awareness of the existence of rich microdata sources and their potential utility for domestic research and policy analysis, in line with the expectations also set out in the Frascati Manual.

2.2. Microdata inputs

The microdata approach depends on the availability of sufficiently comparable microdata, containing variables following the same definitions and based on populations with a sufficient degree of commonality. MicroBeRD relies on official business R&D survey data, complemented for some countries with administrative R&D tax relief microdata wherever available and accessible for analytical purposes.

2.2.1. Sources of microdata

Microdata on business R&D are collected through national business R&D surveys in line with the international standards and guidelines for measuring and reporting R&D as laid out in the OECD Frascati Manual (OECD, 2015).[6] They serve as a basis for official statistics of R&D carried out within countries. For each firm[7], they contain basic demographic information (employment, industry of main activity and, where available, also age, sales and type of ownership) together with detailed information on the firm's R&D. This includes, most importantly, information on R&D performed (intramurally) and funded (extramurally-performed), the type of R&D performed (basic research, applied research, experimental development), sources of funding (e.g. own, other business, government), the structure of R&D costs (e.g. labour, current consumption of goods and services, capital) and R&D employment (expressed in headcount and full-time equivalents).

Business R&D surveys are generally designed to be representative of the population of R&D performing and funding firms in each country. Some countries do not collect information on R&D performers with fewer than 5 or 10 employees, applying another minimum firm-size criterion or exclude certain industries (e.g. agriculture). BERD surveys tend to combine census and sampling survey features to ensure near exhaustive coverage of an activity at the aggregate level which is rather asymmetrically distributed, i.e. a few companies tend to account for a large share of BERD and therefore, known large R&D performers tend to be sampled with certainty. Countries with a sampling framework generally provide ex-ante or ex-post (adjusted for survey-non-response) sampling weights. These allow for the computation of suitably weighted R&D statistics.

Several steps are undertaken in the data preparation phase to ensure data harmonisation and support a robust analysis across countries. Firstly, only firms that actually filled in the R&D survey are kept in the dataset; imputed observations are dropped and the remaining observations are reweighted accordingly. Secondly, micro-firms with fewer than 10 employees, which several countries do not cover in their BERD surveys, are dropped from the analysis. Thirdly, country-level statistics focus on industries which are generally covered in the R&D surveys of all countries: ISIC Rev.4 industries 5-72, excluding 45, 47, 55-56 and 68-69. Automated checks are carried out to identify and drop outlier observations.

Administrative microdata on tax relief provide information on the amount of R&D tax benefits received by corporate tax relief recipients, a subset of the population of R&D performing firms. In some cases, they also include information about the total amount of qualifying R&D expenditure (by type of cost) which may encompass both intramural and extramural R&D. In addition, these administrative data sources typically contain some information about the characteristics of firms (e.g. employment, sales). Prior to applying the microBeRD code, the tax relief microdata are matched by experts within countries to the R&D survey data at the firm-level using unique firm identifiers. By matching business R&D and tax relief microdata, it is possible to identify the corporate R&D performers that make use of R&D tax incentive support and exploit information on the uptake of R&D tax incentives in the analysis.

2.2.2. Measuring public support for business R&D

Information on **direct funding of R&D** is readily available through business R&D surveys (intramural R&D expenditure by sources of funds). The measurement of tax support at the firm level requires additional efforts as few surveys directly collect this information from firms (in line with Frascati Manual recommendations) and, as already noted, administrative data on the amount of tax relief claimed or received is only available for a limited number of countries at present.

The approach adopted in the microBeRD project is to estimate the implications of R&D tax relief provisions through the calculation of **the B-Index** at the level of each firm. The B-Index is a key R&D tax incentive indicator (Appelt et al., 2019) that specifies the cost of R&D to business when investing one additional monetary unit in R&D. **Box 2.1** provides a summary introduction to the B-Index indicator, highlighting its most basic and key defining features.

It is important to note that the B-Index can be computed both for countries that offer R&D tax incentives and for those that do not, while data on the actual amounts of R&D tax relief received by business are accessible for analytical purposes only in selected countries. As a measure of the cost of R&D for one marginal unit of R&D outlay, the B-Index is the customarily adopted indicator for investigating R&D investment decisions at the intensive margin (level of R&D investment).This makes the B-Index the key R&D tax incentive policy variable in the cross-country impact analysis based on micro-aggregated data (**Section Chapter** 3.), while information on the **use and amount of R&D tax incentive support** is exploited in the within-country firm-level analyses (**Section** Error! Reference source not found.), when tax relief microdata are available.

The microdata-based approach allows microBeRD to compute B-Index estimates separately for each firm, based on the cost composition of intramural R&D. These calculations rely on detailed, historic information on the design of R&D tax incentives and general tax system (e.g. corporate income tax rates, depreciation provisions) collected by the OECD. They take into account R&D tax incentive features such as the type of costs that qualify for tax relief (e.g. R&D labour expenditure),[8] the volume-based or incremental nature of the incentive and the rate of R&D tax credit or allowance. **Annex Table B.1** provides a summary description of the main R&D tax incentive design features that feed into the B-Index modelling at the micro-level, taking 2016 – the latest year for which data are available in most countries – as reference year.

The modelling efforts focus on SMEs and large firms, under the assumption of a profitable scenario.[9] The firm-level calculations account for preferential tax incentive rates that apply to specific firms (e.g. SMEs, start-ups, new claimants) in some countries, using the firm type definitions adopted for tax purposes in each country. However, it should be noted that these are model-based imputations that, because of the profitability assumption, may overstate the amount of tax support received by some firms in some countries.

A key advantage of computing the B-Index at the firm level is that it allows for the modelling of thresholds and ceilings which cannot easily be captured using more aggregate country-level data. A number of countries impose limitations on the amount of eligible R&D or tax benefits in order to manage the overall financial burden on public finances and assure a more equitable distribution of R&D tax benefits (OECD, 2018). The microdata make it possible to model changes in the presence or level of ceilings and thresholds and to reflect them in the B-Index estimate of each firm. This is particularly important for modelling the B-Index of large firms, which account for the bulk of R&D in most OECD countries and for which ceilings are thus more likely to be binding.

Box 2.1. Understanding the *B-Index*

What is the B-Index and its Implied Subsidy Rate?

R&D tax relief provisions lower the cost faced by business that perform R&D or pay others to do so on their behalf. The *B-Index* helps identify the expected cost reduction or implied level of *tax subsidy for one extra unit of R&D* invested by firms (Warda, 2001; OECD, 2013). What the *B-Index* literally identifies is a closely related concept: the pre-tax return required for a firm to financially break-even, following a decision to spend one additional monetary unit on R&D, taking into account how much tax is ultimately due. The more generous the tax provisions for R&D, the lower the *before-tax* breakeven economic return required by firms (i.e. the *B-Index*) and therefore the higher the implied marginal R&D tax subsidy. For this reason, it is customary to present this indicator in the converse form of an *Implied Subsidy Rate*, expressed as 1 - *B-Index*.

How is the B-Index calculated?

In its simplest formulation, the B-Index is modelled and computed for a representative firm as the after-tax cost (ATC) of one additional unit of R&D expenditure, normalised by the share of revenue left over after paying tax, so that numbers can be expressed in "before tax" terms. A 'representative firm' in the simplest instance is one with sufficiently large profits to be able to fully exercise the earned tax benefits in the reporting period. In such a case, the *B-Index* value that makes marginal benefits and costs of R&D identical, and its implied subsidy rate, can be expressed as:

$$B\ Index \coloneqq \frac{\mathrm{ATC}}{1-\tau} = \frac{1-\mathrm{A}}{1-\tau}; \qquad Implied\ Subsidy\ Rate \coloneqq 1 - B\ Index = \frac{\mathrm{A}-\tau}{1-\tau}$$

The numerator of the *B-Index* represents the after-tax cost (ATC) of investing one unit of R&D (accounting for all tax provisions in place). In this expression, '*A*' is the combined net present value of tax allowances and credits applying to the marginal R&D outlay and 'τ' is the corporate tax rate. The denominator converts the *after-tax* numerator into pre-tax terms, allowing the comparison across countries with different tax rates. The term *A* is calculated based on modelling work and key parameters defined by tax system features, as explained in the main body of the text.

A simple illustration

In the case of an enhanced, volume-based R&D tax allowance 'θ' (deduction from taxable profits) of 50% on the entire current R&D expenditure for a firm which for simplicity does not have R&D capital expenditures, the calculation of *A* will reflect that current expenditures are by default fully deductible - the benchmark scenario in most countries. In that case: $A=\tau+\tau*\theta=\tau*150\%$ and the Implied Subsidy Rate=50%*τ/(1- τ). In contrast, if no enhanced deductions for R&D are in place, then $A=\tau$, the *B-Index* equals 1 and the subsidy rate is zero. If a company is instead eligible for a tax credit 'c' of 10%, then $A=\tau+c$ and the Implied Subsidy Rate=10%/(1- τ). These examples show that different tax provisions can be modelled and rendered comparable through the *B-Index* indicator and its Implied Subsidy Rate counterpart. Furthermore, it is possible to note that for any given tax rate, e.g. 20%, the same notional subsidy can be granted with different instruments (i.e. 50% enhanced allowance or a non-taxable tax credit of 10%).

Note: For additional information on the B-Index methodology, see OECD (2013, 2018).
Source: Appelt et al. (2019).

2.3. Distributed analysis outputs

The microBeRD code prepared by the OECD secretariat and implemented by national experts within the OECD microBeRD network generates two types of harmonised, non-confidential, microdata-based outputs:

- **Micro-aggregated** statistics at the level of groups of firms defined by features such as country, industry and firm size.
- **Regression** outputs from firm-level analyses within countries.

2.3.1. Micro-aggregated statistics

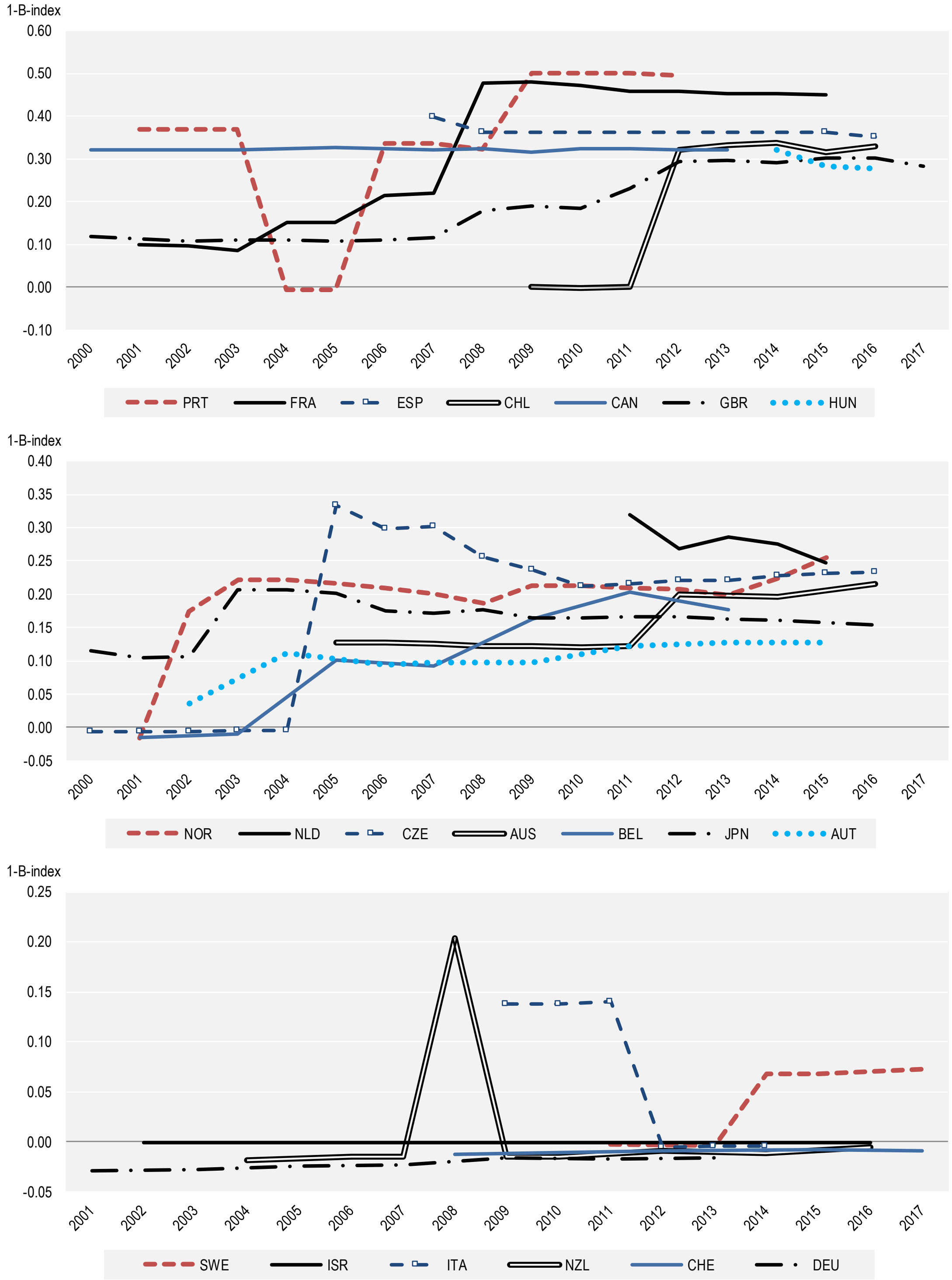
Micro-aggregated indicators capture rich information on R&D performance, funding and employment, the theoretical implied marginal R&D tax subsidy rates (based on the B-Index) and actual amounts of R&D tax relief received by firms, where relevant tax relief microdata are available. They mainly consist of statistical moments – counts, means and percentiles (10th, 25th, 50th, 75th and 90th) – of the underlying variables. These can apply to the primary variables collected in surveys, or derived ratios thereof, such as firm-level R&D intensity (R&D as percentage of sales). The micro-aggregated indicators also include measures of dispersion (standard deviation) and concentration metrics. **Table A.2** provides a summary overview of the key R&D expenditure and R&D tax incentive indicators compiled as part of the distributed analysis.

The statistics are calculated for all firms and various subgroups of firms defined, for example, by STAN A38 industry classification, size class (small, medium-sized, large), age (young, old), ownership (part of group, foreign-owned) or various interactions of these characteristics**. Table A.3** lists the key decompositions (i.e. levels of microdata aggregation) at which the code collects statistics.

Figure 2 provides one example of a micro-aggregated indicator that plays a key part in the analysis presented in this paper. It displays the trends in average implied R&D tax subsidy rates for small companies (assuming these are all profitable), computed based on R&D microdata. To facilitate a cross-country comparison of the generosity of R&D tax incentives, the B-Index is customarily represented as implied marginal R&D tax subsidy rate, defined as 1 minus the B-Index (**Box 2.1**). There is a large variation in R&D tax subsidy rates both across and within countries. A substantial within-country variation is observable for countries that introduced tax incentives (e.g. Czech Republic, Norway) or undertook some significant reforms (e.g. France, Portugal). Whenever countries do not provide R&D tax incentives (e.g. Germany, Switzerland), R&D tax subsidy rates reflect the value of baseline tax provisions (expensing of current and depreciation of capital expenditures). These rates are negative when no immediate write-off is provided for capital expenditures. **Figure A.1**. reports the full set of estimates for small, medium-sized and large firms on a country-by country basis.

Figure 2. Implied marginal R&D tax subsidy rates, small firms, profit scenario, 2000-2017

1-B-index, mean value estimated based on BERD microdata



Note: The figure displays marginal R&D tax subsidy rates based on BERD microdata for the 20 OECD countries participating in the cross-country impact analysis. The subsidy rates are calculated separately for each firm. Values represent averages across all small R&D performing firms in each country and year with the exception of Hungary where a breakdown by firm size is not available and values represent averages across all R&D performing firms. See **Box 2.1** for more details on the interpretation of *B-index* values.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

The distributed analysis facilitates not only the production of microdata based measures of R&D tax subsidy rates but also the production of a range of new types of descriptive R&D statistics. This includes, for example, microdata based indicators on the concentration of business R&D (**Figure A.2**); the comparative share of BERD, direct and tax support accounted for by SMEs (**Figure A.3**), and the relative uptake of direct and tax support measures among corporate R&D performers (**Figure A.4**). Such new indicators feature on the OECD microBeRD website (https://oe.cd/microberd) and in OECD flagship publications such as 2017 OECD Science, Technology and Industry Scoreboard (OECD, 2017) which displayed new indicators on the distribution of business R&D performance by firm size and age, and external sources of R&D funding by size and age. The micro-aggregated indicators produced based on R&D and tax microdata provide not only the basis for new types of descriptive statistics but can also be re-used for more complex types of cross-country analysis on the impact of R&D support policies, as shown in **Section Chapter 3.** .

2.3.2. Regression outputs

An additional type of result from the implementation of the common code is the output that is obtained through the firm-level regressions carried out within countries, which provide estimates of the impact of tax and direct support for business R&D in individual countries. These results are presented in **Section** Error! Reference source not found..

2.3.3. Availability of outputs

Table 1 provides an overview of the status of country participation in the two components of the microdata based impact analysis, distinguishing between the types of microdata sources employed in each of the two analyses.

Table 1. Availability of outputs by type and country

		Micro-aggregated indicators (used for cross-country analysis)	Within-country firm-level analysis	
Policy instrument		Tax incentives & direct support	Tax incentives	Direct support
Source of microdata	R&D survey	8 countries AUT, CHE, DEU, ESP, GBR, ISR, JPN, NZL	2 countries AUT, JPN	10 countries AUT, CAN, CZE, DEU, FRA, ITA, JPN, NOR, NZL, PRT
	R&D survey + tax relief data	12 countries AUS, BEL, CAN, CHL, CZE, FRA, HUN, ITA, NLD, NOR, PRT, SWE	9 countries AUS, BEL, CHL, CZE, FRA, ITA, NOR, PRT, SWE	-

Note: To ensure the reliability of firm-level estimates, results are only reported when the number of treated firms and the number of control firms are each at least 50.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

At the time of reporting, 20 countries have completed the final round of distributed analysis undertaken as part of the first phase of the microBeRD project (2016-19). These have been included in the cross-country impact analysis, based on micro-aggregated R&D microdata, reported in **Section 3**, namely: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, and the United kingdom. Two of them (Germany and Switzerland) did not provide R&D tax incentives during the time period considered in this study (2000-2017). **Table A.1** shows the countries and years which are included in the micro-aggregated impact analysis based on BERD microdata. 12 out of the

18 countries that offered R&D tax support during this period were able to extend the analysis to R&D tax relief microdata.

Firm-level regression results on the impact of R&D tax incentives are reported for a total of 11 countries (Australia, Austria, Belgium, Chile, Czech Republic, France, Italy, Japan, Norway, Portugal and Sweden). To ensure the reliability of estimates, firm-level results are only reported when the analysis is based on a sufficiently large number of firms, specifically when both the number of treated firms and the number of control firms are at least 50. In 2 countries, the firm-level analysis has been performed based exclusively on R&D survey data, while in 9 countries, the analysis relies on matched R&D tax relief and R&D survey microdata. Firm-level results on the impact of direct support, estimated based on R&D survey data, are available for 10 countries.

Chapter 3. Cross-country analysis based on micro-aggregated data

The cross-country analysis presented in this section aims to assess the impact of R&D tax incentives on business R&D performance and to explore the underlying mechanisms (e.g. price vs quantity effects) and heterogeneity of effects across different types of firms (e.g. by firm size, industry). While the main part of the analysis focuses on the impact of R&D tax incentives, this work also examines, on an exploratory basis, the effect of other policy instruments – the level of corporate income taxation and direct funding of business R&D– and their interaction with R&D tax incentives.

This section describes the estimation methodology and presents the results from the cross country impact analysis. This analysis focuses on input additionality, i.e. the effect of R&D tax incentives on R&D inputs (R&D expenditure and R&D personnel). Depending on the availability and accessibility of relevant microdata within participating countries, future work could also examine the impact of tax and direct support on innovation output and wider economic outcomes, such as employment and productivity growth.

The analysis is based on pooled micro-aggregated data for 20 countries, which represent an unbalanced panel covering the years 2000-2017 (see **Table A.1**). Observations are defined at the level of groups of firms within the same **country, industry** (36 STAN A38 industries) and **size class** (small, medium, large). This database, pooled by the OECD secretariat, was constructed in a distributed fashion from microdata by calculating means, counts and totals of relevant variables across all firms within each country-industry-size class (see **Section Chapter 2.** for more detail).

A key advantage of studying the impact of R&D tax incentives at the country-industry-size class level is that it allows capturing much more variation in R&D tax subsidy rates than what is possible at more aggregate levels of data (e.g. country, industry). Smaller firms often benefit from preferential tax credit or allowance rates, and they are less likely to find R&D expenditure thresholds and ceilings to be binding. The cost composition of intramural R&D expenditure also varies across firms operating in different industries and consequently the share of R&D expenditure that is eligible for tax support. This analysis is able to exploit these sources of variation both within and across countries.[10]

3.1. Methodology

The first part of this section describes the estimation strategy adopted in the cross-country impact analysis, showing how estimates of the elasticity of business R&D performance to the price of R&D (user cost) can be derived. While R&D price elasticities give a positive indication of tax incentives' capacity to stimulate R&D spending, they do not directly measure R&D input additionality – the extent to which R&D tax incentives are effective in generating additional R&D expenditure beyond the level that would have been observed in their absence. The R&D "incrementality ratio" (IR, or "bang for the buck - BFTB") which specifies the change in R&D investment per dollar of foregone tax revenue, provides such a measure. The second part of this section explains how incrementality ratios can be derived from price elasticity estimates.

3.1.1. Estimation strategy

The estimation is based on an econometric model that links firms' decisions to invest in R&D to the user cost of R&D. The latter consists of two elements: an economic component (sum of economic depreciation and real interest rate) and a tax component – the B-Index –

that captures features of the general tax system, including the implications of R&D tax incentives (OECD, 2018). Tax incentives, where available, reduce the B-Index. Using micro-aggregated data on business R&D expenditure and the B-Index at **country-industry-firm size-year level**, the cross-country regression analysis estimates the R&D price elasticity of business R&D, i.e. the percentage change in R&D investment resulting from a 1% reduction in the user cost of R&D[11], based on the following specification:

$$logY_{cist} = \sum_{g \in G} \beta_g^{TAX} \, logBIndex_{cist} + \beta^{VA} logVA_{cit} + \gamma_{cis} + \gamma_{it} + \gamma_{st} + \varepsilon_{cist} \quad (1)$$

The main outcome variable of interest (Y_{cist}) is total intramural R&D expenditure by firms in country c, industry i, size class s and year t.[12] In addition, the analysis adopts a range of other outcome variables. Firstly, it tests if the effects differ across different types of R&D costs and by orientation of R&D. Secondly, the analysis seeks to explore whether the estimated effects are driven by an increase in the number of R&D personnel or by price effects (increases in researcher wages due to increasing quality or fixed short-term supply of researchers).[13] Thirdly, it examines if the tax incentives encourage R&D not only at the intensive margin (i.e. by increasing R&D expenditures among existing R&D performers) but also at the extensive margin (i.e. by increasing the number of R&D performers). **Table 2** provides the list of variable names and descriptions of the outcome and explanatory variables employed in the analysis.

$Bindex_{cist}$ is the R&D tax incentive policy variable in the micro-aggregated analysis, representing the mean B-index (profit scenario) for each group of firms. This variable enters the analysis in log terms. The coefficient β_g^{TAX} identifies the user-cost elasticity, i.e. the proportional change in total intramural R&D of firms in a given group for a percentage change in the average B-index for that group of firms. The elasticities can be allowed to vary across different groups of firms (e.g. there can be a different β_g^{TAX} for small, medium and large firms). This allows for the estimation of heterogeneous effects of R&D tax incentives across different types of firms.

Industry-level value added (VA_{cit}), sourced from the OECD STAN database (http://oe.cd/stan), enters the regression as control variable to account for industry output. All regressions control for a rich set of fixed effects. The term γ_{cis} captures all characteristics of firms in a particular country, industry and size class (country-industry-size fixed effects) that do not change over time. This implies that the regression analysis exploits only the variation within country-industry-firm size units over time. Moreover, the regression analysis controls for industry-year fixed effects (γ_{it}) and size-year fixed effects (γ_{is}); by doing so, it controls, for example, for the differential effects of the global economic slowdown on the R&D performance of firms in different industries and firms of different size respectively. Finally, ε_{cist} is a time-varying residual – a summary term for effects not captured by any of the other variables.

Table 2. Variables used in the cross country analysis based on micro-aggregated data

Outcome variables	
R&D performance	
Intramural	Total intramural R&D expenditure by firms [in the relevant cell/group]
Labour	Total R&D labour expenditure by firms
Other current	Total other current R&D expenditure by firms
Capital	Total R&D capital expenditure by firms
Extramural	Total extramural R&D expenditure by firms
Intramural (own-funded)	Total intramural (own-funded)
Intramural (own-funded) + Extramural	Total intramural (own-funded) and extramural R&D expenditure by firms
Research	Total intramural R&D expenditure by firms devoted to basic and applied research
Development	Total intramural R&D expenditure by firms devoted to experimental development
Price effects	
R&D employment (headcount)	Total R&D employment (headcount) by firms
Implied R&D unit labour cost (headcount)	Mean R&D labour expenditure–R&D employment (headcount) ratio across firms
R&D employment (FTE)	Total R&D employment (full-time-equivalents) by firms
Implied R&D unit labour cost (FTE)	Mean R&D labour expenditure – R&D employment (full-time-equivalents) ratio across firms
Intensive vs. extensive margin	
R&D performers	Number of R&D performing firms
2-year growth in number of R&D performers	2-year growth (log change) in number of R&D performers
2-year growth in intramural R&D	Mean 2-year within-firm growth (log change) in intramural R&D expenditure
Explanatory variables	
R&D tax incentive support	
BIndex	Mean B-Index (tax component of the user cost of R&D) across firms
BIndexSyn	Mean synthetic B-Index (based on 2 year R&D lag) across firms
d2logBIndexSyn4	Mean synthetic 2-year log change in B-Index (based on 4-year R&D lag) across firms
BIndexTax	Mean B-Index across firms based on R&D tax support use
Control Variables	
Value added	Total value added at country-industry (A38) level from the OECD STAN database
Fixed effects	Country-industry-size, industry-year, size-year dummy variables
Interaction variables	
Firm size	
Small	Dummy variable for small firms (10-49 employees)
Medium	Dummy variable for medium-sized firms (50-249 employees)
Large	Dummy variable for large firms (250 or more employees)
Age	
Young	Dummy variable for firms with less than 5 years of age
Old	Dummy variable for firms with 5 or more years of age
Industry	
Manufacturing	Dummy variable for firms in manufacturing (A38: 10-33)
Services	Dummy variable for firms in services (A38: >=45)
Medium & High R&D-intensive	Dummy variable for firms in medium (A38: 20,27,28,29,62) and high R&D intensive (A38: 21,26,72) industries
R&D-intensive	Dummy variable for firms in high R&D-intensive industries (A38: 21,26,72)
Digital-intensive	Dummy variable for firms in digitally-intensive industries (A38: 26,28,29,61,62,64,69,72,73,77,94)
Knowledge-intensive	Dummy variable for firms in knowledge-intensive service industries (Eurostat classification, see footnote 40)
Initial R&D performance	
Initial R&D performance	Average intramural R&D expenditure of firms in the first year of observation
Low, medium & high initial R&D performance	Dummy variable for firms with average intramural R&D in the first year of obs. of less than USD 400 000 (low), USD 400 000 – 2 000 000 (medium) and more than USD 2 million (high)
Other policy instruments	
Corporate income taxation	Statutory non-targeted corporate income tax rate
Direct funding of business R&D	Total government-financed R&D received by firms (lagged 2 years)

Note: Variables are reported at the level of groups of firms (cells) defined by the same country, industry (36 STAN A38 industries) and size class (small, medium, large).
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

The B-Index is typically introduced as exogenous policy variable in cross-country studies based on country or industry level data (Guellec and Van Pottelsberghe De La Potterie, 2003; Thomson, 2017). At the micro level, however, the B-Index depends on the level of business R&D expenditure of each firm (e.g. the rate of R&D tax credit is reduced once a certain R&D expenditure threshold is reached). This could render the B-Index endogenous. To address the potential endogeneity of the micro-aggregated B-Index indicator and avoid estimation bias, a synthetic version of the B-Index ($BIndex_t^{syn}$) indicator (Agrawal et al., 2020; Rao, 2016) is adopted in the main specifications of the cross-country analysis. The firm-level synthetic measure of the B-Index (in period t) is obtained by applying the R&D tax incentive design in year t to the R&D performance of firms in year t-2. This ensures that the current user cost of R&D does not depend on the level and structure of contemporary R&D spending.

$$BIndex_t^{syn2} := BIndex_t(RD_{t-2}) \tag{2a}$$

For an additional analysis of the relationship between changes in the B-Index and changes in R&D investment over a two-year time span, a measure of the synthetic two-year log change in the B-Index ($d2logBIndex_t{}^{syn4}$) can similarly be defined as log difference between a B-Index based on design in year t and R&D performance in year t-4 and a B-Index based on design in year t-2 and R&D performance in year t-4. This approach ensures that R&D expenditure is kept fixed at the levels in t-4 and only the R&D tax incentive design varies over time.

$$d2logBIndex_t{}^{syn4} := logBIndex_t(RD_{t-4}) - logBIndex_{t-2}(RD_{t-4}) \tag{2b}$$

$BIndex_{cist}$ or $BIndex_{cist}^{syn2}$ do not reflect whether firms actually use R&D tax incentives. For this reason, the estimated R&D price elasticities can be seen as "intention-to-treat" estimates which are likely to underestimate the effect of R&D tax incentives for firms that actually used them. To explore this, an adjusted version of the B-Index indicator that takes into account the actual uptake of R&D tax support by firms is calculated for the subset of countries where R&D tax relief microdata are available. For firms that receive R&D tax support, the tax support-based version of the B-Index is identical to the standard B-Index indicator ($BIndex_t$). In the case of firms that do not receive such support, R&D tax incentive design features are disregarded in the computation of the B-Index and only baseline tax deductions – expensing of current expenditure and standard depreciation provisions for capital expenditures – are accounted for ($BIndex_t^{Baseline}$).

$$\begin{aligned} BIndex_t^{Tax} &:= BIndex_t \; if\ tax\ support \\ BIndex_t^{Tax} &:= BIndex_t^{Baseline} \; if\ no\ tax\ support \end{aligned} \tag{3}$$

Tax incentive use is likely to be endogenous to firms' R&D performance, so estimating the effect of $BIndex_t^{Tax}$ would likely result in biased estimates. For this reason, an instrumental variables estimation (IV) is employed, where $BIndex_t^{Tax}$ is instrumented with the synthetic B-Index ($BIndex_{cist}^{syn2}$). To explore the heterogeneity of the estimated effects, the B-Index variable ($BIndex_{cist}^{syn2}$) is interacted with various firm characteristics such as firm size, industry sector and initial R&D intensity. **Table 2** reports the full list of interaction variables. With the exception of variables that are defined in growth rates, i.e. log changes (2-year growth in number of R&D performers, 2-year growth in intramural R&D, synthetic 2-year log change in the B-Index), normalised interaction terms (initial average R&D performance), dummy variables, and the corporate income tax rate, all exploratory and outcome variables enter the regression in log terms.

The second part of the analysis examines the role of other policy instruments – corporate income taxation and direct forms of public R&D funding – and their interaction with R&D tax incentives. The level of corporate income taxation is measured by the statutory combined (central and sub-central) corporate income tax rate (CIT_{ct}) – non-targeted and targeted small business CIT rates, where applicable – and direct support by the (logged) amount of direct funding received by firms in a given country, industry and size class ($\log DF_{cist-2}$). Both policy variables enter the regressions as separate explanatory variables and interacted with the *B-Index* ($BIndex_{cist}^{syn}$).[14] The estimated equations are as follows:

$$logY_{cist} = \beta^{TAX}\, logBIndex_{cist} + \beta^{CIT}\, CIT_{ct} + \beta^{TAXCIT}\, logBIndex_{cist} * CIT_{ct} + \beta^{VA} logVA_{cit} + \gamma_{cis} + \gamma_{it} + \gamma_{st} + \varepsilon_{cist} \quad (4a)$$

$$logY_{cist} = \beta^{TAX}\, logBIndex_{cist} + \beta^{DF}\, \log DF_{cist-2} + \beta^{TAXDF}\, logBIndex_{cist} * \log DF_{cist-2} + \beta^{VA} logVA_{cit} + \gamma_{cis} + \gamma_{it} + \gamma_{st} + \varepsilon_{cist} \quad (4b)$$

By construction (government-financed BERD is one component of BERD), direct funding is directly linked to the contemporaneous level of intramural R&D. To avoid simultaneity bias, the direct funding variable is lagged by two years ($\log DF_{cist-2}$).[15] Moreover, own-funded intramural R&D is used as outcome variable, netting out the contribution of direct funding and other external sources of R&D funding.[16] This means that the elasticity parameter estimated for direct funding represents a net elasticity, specifying the percentage change in BERD beyond the level of direct support provided. The R&D price elasticities estimated based on the B-Index reflect gross elasticities, by contrast, independent of whether the analysis adopts intramural R&D or own-funded intramural R&D as dependent variable.[17] They specify the percentage change in BERD gross of the R&D tax subsidy provided. While gross and net elasticities are not directly comparable, net incrementality ratios can be converted into gross incrementality ratios (**Section 3.1.2**), facilitating a comparison of the input additionality of tax and direct support.

Table 3 presents the summary statistics for the outcome and explanatory variables employed in the micro-aggregated impact analysis. The analysis covers R&D performing firms with 10 or more employees, and it includes all industries for which information is available. All financial variables are converted into 2005 USD using purchasing power parity (PPP) exchange rates. R&D expenditure is deflated using GDP-PPP deflators. Value added is deflated using industry-specific deflators from the OECD STAN database. The estimation database counts 9 679 country-industry-size class-year observations for which the baseline regressions in their simplest specification can be run. However, not all variables are available for all these observations, i.e. more demanding specifications are based on smaller data samples.

The median country-industry-size class group of firms incurs USD 35 million of intramural R&D expenditure, while the average is nearly 10 times larger. The median number of R&D performers per group (country-industry-size class) is 37, and the average firm-level R&D performance within firm groups is about USD 700 000 at the median. The average R&D wage in the median firm group is around USD 39 000 per person and USD 56 000 per full-time equivalent. Across firm groups, the average B-Index amounts to 0.83, implying that R&D tax incentives provide a sizeable marginal R&D subsidy rate of 17%. The average firm group receives about USD 14 million of direct funding, while the median firm group receives around USD 1 million. Since observations correspond to cells defined at country-industry-size class level, cells for small, medium-sized and large R&D performers account for similar shares of the estimation database.[18] Slightly over half of the observations fall within manufacturing, a third in services and the rest in other macro sectors such as mining and utilities. Sectors classified as medium or high R&D intensive account for a third of the sample, R&D intensive sectors alone for 12%. About a third of the observations are assigned to digital-intensive industries.

Table 3. Summary Statistics for outcome and explanatory variables

Country-industry-firm size level, 2000-2017

	N	Mean	Median	SD	Min	Max
Intramural R&D (000 USD)	9679	314766	35128	1270247	1	21152974
Labour (000 USD)	9057	160315	19124	587475	0	12106839
Other current (000 USD)	8698	146454	11716	664666	0	12434796
Capital (000 USD)	7330	33346	4037	116366	0	1733442
Research (000 USD)	7945	138932	15995	504980	0	11152857
Development (000 USD)	7924	218617	22171	966408	0	17442246
Extramural R&D (000 USD)	6494	81235	5075	433734	0	9823227
Intra. (own-funded)	8702	317583	29175	1508713	0	28046316
Intra. (own-funded) + Ext. (000 USD)	8962	327639	30001	1519361	1	28046316
R&D employment (headcount)	7314	1311	154	4935	0	123825
Implied R&D unit labour cost (headcount, 000 USD)	7273	46	39	39	0	780
R&D employment (FTE)	7967	1678	229	5317	0	116424
Implied R&D unit labour cost (FTE, 000 USD)	8125	62	56	42	0	780
Number of R&D performers	9679	83	37	130	3	1794
Average intramural R&D (000 USD)	9679	5210	700	17444	0	720387
2-year log change in number of R&D performers	7776	12.7%	8.0%	38.3%	-195.0%	340.0%
2-year log change in intramural R&D	6411	2.5%	2.5%	27.0%	-202.0%	160.0%
BIndex	9679	0.83	0.84	0.14	0.41	1.09
BIndexSyn	6837	0.88	0.83	0.32	0.41	2.26
d2logBIndexSyn4	4937	-0.03	0.00	0.11	-0.53	0.50
BIndexTax	4452	0.88	0.91	0.12	0.46	1.11
Value added (000 000 USD)	9679	30306	12793	50645	49	581333
Corporate Income tax rate	9678	29%	30%	6%	10%	42%
Direct funding of BERD (000 USD)	8847	14062	1017	70821	0	1529246
Small	9679	34%	0%	47%	0%	100%
Medium	9679	34%	0%	47%	0%	100%
Large	9679	32%	0%	47%	0%	100%
Manufacturing	9679	54%	100%	50%	0%	100%
Services	9679	34%	0%	47%	0%	100%
Medium and high R&D-intensive	9679	35%	0%	48%	0%	100%
High R&D-intensive	9679	12%	0%	33%	0%	100%
Digital-intensive	9679	35%	0%	48%	0%	100%
Knowledge-intensive	9679	19%	0%	39%	0%	100%

Note: The summary statistics presented in this table are based on micro-aggregated data. Observations are defined at the country-industry-size class level. See **Table 2** for variable definitions. Monetary variables are stated in 2005 US dollars using purchasing power parity exchange rates.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

3.1.2. Deriving input additionality estimates

Based on the estimated elasticities of business R&D to the user cost (B-Index) and direct funding of BERD, it is possible to derive measures of input additionality in the form of the so-called R&D "incrementality ratio", also known as "bang for the buck". This ratio specifies the change in R&D investment per dollar of foregone tax revenue. Incrementality ratios indicate the extent to which R&D support policies are effective in generating additional R&D expenditure beyond the counterfactual level that would have been observed in their absence.

Different methodologies for measuring R&D input additionality are used in the literature.[19] While a number of micro level studies[20] compute input additionality estimates, macro-level studies tend to report user cost elasticities and not derive input additionality estimates as such.[21] As Montmartin and Herrera (2015) note, this is related to the hitherto existing lack of country-level time-series data on R&D tax support (GTARD). One exception is the cross-country study by Thomson (2017) who estimates the elasticity of R&D investment with respect to tax price based on industry-level data covering a panel of 29 industries in 26 OECD countries over the years 1987 to 2006. Based on this elasticity he derives an analytical measure of the bang for the buck.

The method adopted in this paper – akin to the approach adopted by Thomson (2017) – consists of an analytical derivation of the incrementality ratio from the elasticity of business R&D expenditure to the B-index. The estimated elasticity parameter β_g^{TAX} based on equation (4a) denotes the expected percentage change in BERD resulting from a marginal percentage change in the B-Index, i.e. $\beta_g^{TAX} = \frac{dlogBERD}{dlogBIndex}$. Based on this elasticity, the gross incrementality ratio (IR), i.e. marginal change in BERD resulting from a marginal change in government tax relief for R&D (GTARD) can be derived as follows:

$$IR^{Tax} := \frac{dBERD}{d\widehat{GTARD}} = \left(\frac{1}{1-\tau}\right) * \frac{\beta_g^{TAX}}{\beta_g^{TAX}(1 - BIndex) - BIndex} \qquad (5)$$

where τ is the statutory combined (central and sub-central) corporate income tax rate (CIT) – non-targeted and targeted small business CIT rates, where applicable. As the formula depends on the B-index and the corporate tax rate, the incrementality ratio, in principle, varies across countries, firm types and industries and over time. The average B-index and corporate income tax rate across all industry-size class groups in the sample is applied in the calculation.

It is important to note that the analytical derivation in (5) is based on the assumption that the implied marginal tax subsidy rate (1-BIndex) applies to each unit of R&D outlay, so that $\widehat{GTARD} = (1 - BIndex) * (1 - \tau) * BERD$ (Appelt et al., 2019).[22] This implies substituting the average tax subsidy rate with the marginal R&D tax subsidy (1-B-Index). A number of countries impose limitations (floors, thresholds, ceilings) on the amount of qualifying R&D expenditure or value of R&D tax benefits.[23] This can drive a gap between marginal and average tax subsidy rates. For example, in the case of incremental tax incentives where only R&D expenditure in excess of a predefined base amount qualifies for support, the average subsidy rate will be smaller than the marginal subsidy rate up to the point of any ceiling that may additionally apply. When ceilings or thresholds apply on the amount of qualifying R&D expenditure or value of R&D tax benefits, the average subsidy rate can be expected to exceed the marginal one for firms for which this limitation is binding. This approximation is made due to the fact that not all countries have access to R&D tax relief microdata and flagged by the representation of GTARD ($\widehat{GTARD}$).

The semi-elasticity parameter estimated for statutory combined (central and sub-central) CIT rates (β^{CIT}) as indicated in equation (4a) represents the percentage change in intramural R&D (Intra) associated with a one percentage point CIT reduction. The (gross) incrementality ratio for CIT reductions can be approximated by dividing the semi-elasticity β^{CIT} by the ratio of forgone CIT revenues to intramural R&D.[24]

$$IR^{CIT} := \frac{\beta^{CIT}}{forgone\ CIT\ revenue} \quad (6)$$

The elasticity parameter estimated for direct funding (β^{DF}) as indicated in equation (4b) represents the percentage change in own-funded intramural R&D (IntraInt), i.e. the change in BERD net of the amount of direct funding received from all other sources, including other business.[25] The (net) incrementality ratio for direct funding can be obtained by dividing the elasticity β^{DF} by the share of direct funding in own-funded intramural R&D.

$$IR^{Direct} := \frac{\beta^{DF}}{DF/IntraInt} + 1 \quad (7)$$

This net incrementality ratio estimate can be converted into a gross estimate by adding back the one unit of government support ($IR^{Direct} := \frac{dBERD}{dDF} = \frac{dIntraInt}{dDF} + 1$). The incrementality ratios reported in this publication are gross estimates, i.e. they include the amount of R&D subsidy provided by government. This means that an incrementality ratio of less than 1 indicates some crowding out of private R&D, while an incrementality ratio larger than 1 implies net R&D input additionality (crowding-in of private R&D).

3.2. Results for R&D tax incentives

This section presents the results from the micro-aggregated impact analysis. The main part of the analysis focuses on the impact of R&D tax incentives, i.e. the link between the user cost of R&D (B-Index) and business R&D at country-industry-firm size level. This first part of the analysis gives insights into how R&D tax incentives affect R&D expenditure and cost components, and it provides evidence on the mechanisms that drive the overall effects, including the heterogeneity of effects across different types of firms. It concludes with a presentation of R&D input additionality estimates (incrementality ratios) derived from the elasticity estimates (main specifications). This is followed by exploratory evidence on the role of corporate income taxation and direct funding of business R&D.

3.2.1. The impact of R&D tax incentives

Effects on overall R&D investment

The baseline results from the micro-aggregated impact analysis at country-industry-firm size (cell) level are summarised in **Table 4**. Coefficients indicate the elasticity of R&D expenditure to the user cost of R&D (B-Index), which represents the percentage change in a cell's total R&D expenditure resulting from a one percentage change in the cell's average B-Index. The primary outcome variable is total intramural R&D expenditure in each cell, except for specifications (7) and (9-11) where total intramural (internally funded) and the sum of the latter and extramural R&D expenditure denote the dependent variables respectively. Regressions generally include controls for industry-level value added and country-industry-size, industry-year and size-year fixed effects (FE).

With some variation across specifications, estimates based on micro-aggregated R&D survey data imply an overall user cost elasticity of R&D expenditure around -0.6. The simplest specification, using the contemporary B-Index as policy variable, no control variables and common year effects yields an elasticity of -0.58 (column 1). The inclusion of industry-year and size-year fixed effects does not affect the estimate (column 2), and neither does the inclusion of value added as a control variable (column 3).

When the B-Index is calculated based on R&D expenditure two years earlier ($BIndex_{cist}^{syn2}$) and value added is lagged by two years, to avoid the potential bias arising from the simultaneity of the *B-Index* and R&D expenditure, the estimated elasticity *increases* (column 5). However, this increase is not driven by a change in the sample (observations for which lagged R&D expenditure is not available are dropped), as an estimate based on the reduced sample but a contemporaneous B-Index (column 4) is similar to that found in the initial specification (column 3)

Intramural R&D, the outcome variable in the first five specifications (columns 1-5), includes R&D performed by firms which may be funded through own and external sources (e.g. government, business or private-non-profit institutions). The effect of tax incentives on intramural R&D funded through own sources is somewhat stronger than the one on total intramural R&D (see columns 6 and 7).

Tax incentives may not only induce firms to perform more R&D but also to outsource R&D to third parties. The estimated elasticity slightly increases when R&D funding (i.e. internally funded intramural R&D expenditure and extramural R&D expenditure) is used as outcome variable rather than R&D performance, (i.e. intramural R&D funded through own and external sources, compare columns 8 and 9).

The user cost elasticities of around -0.6 found here for intramural R&D are slightly higher than the short-term elasticities found in other cross-country studies. Based on a static IV estimation, Bloom, Griffith and Van Reenen (2002) find an elasticity of -0.5, while their dynamic estimates imply a short-term elasticity of -0.14 and a long-term elasticity around -1. Guellec and Van Pottelsberghe De La Potterie (2003) find both the short-term and the long-term elasticity to be around -0.3. Applying a dynamic estimation to industry-level data, Thomson (2017) finds a short-term elasticity of -0.5.[26]

The user cost measures adopted in the literature and this paper may in turn overstate the actual level of support because all firms are assumed to be profitable. Provisions for loss-making firms (carry-overs, refunds) do not feed into the modelling as it is not possible to identify the baseline tax liability of firms. This may potentially underestimate the price elasticity of R&D. While this study has not yet been able to leverage data on the profitability or tax liability of firms, it can exploit information on the uptake of R&D tax incentives for some countries, refining the existing measure of the cost of R&D.

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Table 4. R&D price elasticity by measure of user cost – baseline specification

Measure of user cost	BIndex			BIndexSyn							BIndexTax
Dependent variable: log expenditure on	Intramural			Intramural		Intramural	Intramural (internal)	Intramural	Intramural (internal) + Extramural		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
log BIndex	-0.577***	-0.578***	-0.571***	-0.565***							
	(0.077)	(0.066)	(0.065)	(0.073)							
log BIndexSyn					-0.665***	-0.611***	-0.735***	-0.623***	-0.696***	-0.764***	
					(0.075)	(0.078)	(0.081)	(0.077)	(0.081)	(0.157)	
log BIndexTax											-1.009***
											(0.208)
log Value Added			0.281***								
			(0.072)								
log Value Added t-2				0.168**	0.176**	0.143*	0.081	0.147*	0.071	-0.052	-0.057
				(0.073)	(0.073)	(0.075)	(0.075)	(0.075)	(0.075)	(0.143)	(0.139)
Country-industry-size class FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year FE	Y										
Industry -Year FE		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Size class-Year FE		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	9679	9679	9679	6822	6822	6283	6283	6418	6418	3118	3118
Countries	20	20	20	18	18	17	17	17	17	10	10

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. The full sample covers 20 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. Results in columns 4-5 are based on observations with non-missing values of BIndexSyn and do not include Spain and Switzerland. Results in columns 6-9 are based on observations with non-missing values of internally funded R&D expenditure and additionally do not include Canada. Results in columns 10-11 are based on observations with matched tax relief microdata and include Australia, Belgium, the Czech Republic, France, Hungary, Italy, the Netherlands, Norway, Portugal and Sweden. Results reported in column 11 are based on an instrumental variables estimation, using $BIndex_{cist}^{syn}$ as an instrument for $BIndex_t^{Tax}$.

Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Accounting for the actual use the R&D tax incentives increases (in absolute value) the estimated elasticity by about a third. This is likely explained by the fact that the R&D price elasticity estimated based on $Bindex_{cist}$ or $BIndex_{cist}^{syn2}$ reflects an "intention-to-treat" effect across the firm population, independently of the actual uptake of R&D tax incentives by firms. As noted in **Section 3.1.1**, this can lead to an underestimation of the price elasticity of R&D when only a fraction of firms effectively used R&D tax incentives.

To explore this, the baseline specification is re-estimated using the tax-support-based version of the *B-Index* indicator ($BIndex_t^{Tax}$), available for a subset of countries with access to R&D tax relief microdata. Since firms' decision to use the tax incentives is endogenous, $BIndex_t^{Tax}$ is instrumented with $BIndex_{cist}^{syn2}$. Taking into account the incentive use yields a substantially larger elasticity estimate of -1.01 (column 11)[27]. This suggests that the existing R&D price elasticities obtained in the literature, which generally do not reflect R&D tax incentive use, might understate the actual price elasticity of R&D.[28]

The elasticity of R&D to the *B-Index* does not seem to vary with the size of the B-Index. In an extra exercise, squared terms of the standard and synthetic version of the log B-Index are added to the specification (**Annex Table C.1**). This exercise does not yield any evidence of non-linear effects, as the interaction terms are not statistically different from zero.

The estimates presented here would overstate firms' true responsiveness to tax incentives if part of the effect were driven by a relabelling of non-R&D expenditure as R&D.[29] Relabelling would imply that some non-R&D related expenditures decline as R&D expenditure increases. Despite some early suggestive evidence (Eisner et al., 1984), recent studies suggest that relabelling does not appear to be a serious problem in advanced economies. Guceri and Liu (2019), using detailed administrative data for the UK, do not find evidence of such a phenomenon. Agrawal et al. (2020) similarly find no evidence of relabelling in Canada, and evidence from US and Australian tax auditors, discussed by Hall and Van Reenen (2000), also does not indicate a substantial relabelling. In contrast, Chen et al. (2018) find that about 30% of the response to R&D tax incentives in China was due to relabelling, suggesting that relabelling may be more of an issue in some countries than others, depending on instrument design and implementation features. The evidence is therefore inconclusive regarding the role of relabelling as a factor explaining observed R&D impacts, with true impacts possibly depending on the extent to which effective ex-ante approval or ex-post audit mechanisms are in place.

Such mechanisms can in turn contribute to increase the cost to government and burden to business. It should be noted that R&D tax incentives may encourage business practices (e.g. effective planning and record keeping) that transform non R&D activities into legitimate R&D by means of compliance with the formality criterion in the definition of R&D (OECD, 2015). This may be part of the policy rationale for using such an instrument. Exploring the link between the availability of non-discretionary tax incentives and the incentives within business to either re-label or formalise and evolve existing activities is a key priority for future OECD work.[30].

The results could also overstate the effect of tax incentives on global R&D investment if the observed effects are partly attributable due to R&D relocation across countries. The effect of R&D tax incentives on the R&D location choices of MNEs remains a relatively unexplored issue. The estimation of this effect is complicated by a scarcity of relevant data and the complex interaction of tax regimes across and within countries. The available evidence suggests that the volume of R&D conducted in one country responds to changes in the cost of doing R&D in competing jurisdictions – be it country (Bloom and Griffith, 2001; Billings, 2003; Montmartin and Herrera, 2015) or state level (Wilson, 2009). A similar conclusion is reached in recent work, examining the link between taxation and innovation. Akcigit, Baslandze and Stantcheva (2016) and Akcigit et al. (2018) find that personal and corporate taxes induce inventor mobility and the relocation of inventive activity across countries. [31] Moretti and Wilson (2017) similarly document that personal and corporate taxes influence star scientists' migration patterns across US states.

However, what portion of the estimated effects is exactly due to relocation is unclear. Resolving this question calls for additional research. While it is, due to data confidentiality requirements, not possible to pool national R&D microdata and track the global R&D activities of firms such as MNEs, this question could potentially be explored in more detail in the context of the cross-country microdata setting of the microBeRD project. For example, in the cross-country analysis, by estimating the elasticity of R&D to the user cost of R&D in adjacent countries, and the within-country firm-level analyses, by estimating the effect of R&D tax incentive policy changes in neighbouring countries on the R&D performance of domestic firms. Such analyses could give new insights into the potential scope of R&D relocation across a broader set of OECD countries.

Type of costs

The elasticity of R&D expenditure to the user cost of R&D can vary across different components of intramural R&D expenditure – labour and capital expenditures – and between extramural and intramural R&D. **Table 5** presents the R&D price elasticity estimates based on the synthetic B-Index by type of cost, based on a panel of 17 countries where relevant data on extramural R&D expenditure are available.

Table 5. R&D price elasticity by type of cost

Dependent variable:	Intramural	Labour	Other Current	Capital	Intramural	Extramural
log R&D expenditure	(1)	(2)	(3)	(4)	(5)	(6)
log BIndexSyn	-0.582***	-0.553***	-0.707***	-0.950***	-0.618***	-0.984***
	(0.076)	(0.073)	(0.110)	(0.149)	(0.087)	(0.169)
Observations	5437	5437	5437	5437	4867	4867
Countries	16	16	16	16	17	17

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects, industry-year fixed effects and size class-year fixed effects. The first set of specifications (1-4), based on intramural R&D expenditure by type of cost, covers 16 OECD countries: Australia, Austria, Belgium, Chile, the Czech Republic, France, Germany, Hungary, Israel, Italy, Japan, the Netherlands, Norway, Portugal, Sweden, and the United Kingdom. Results in columns 5-6, based on non-missing values of intramural and extramural R&D expenditure, cover 17 countries: the 16 countries above, excluding Australia and including Canada and New Zealand.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

The analysis of R&D impacts by type of cost suggests that tax incentives have a somewhat stronger effect on capital and subcontracted (extramural) R&D expenditure than on labour and other current R&D. The price elasticity for labour and other current R&D expenditure is very similar to that for total intramural R&D expenditure (around -0.6), while the elasticities for capital expenditure and extramural R&D expenditure are significantly greater in absolute terms, around -0.95, mainly due to the fact that large firms show little responsiveness to tax incentives in terms of current R&D (see analysis of heterogeneous effects by firm size below). A firm-level study for Canada by Agrawal et al. (2020) similarly finds a stronger effect for R&D tax incentives on subcontracted R&D compared to R&D performed in-house, while Rao (2016) finds a similar responsiveness of intramural and extramural R&D expenditure in the US.

Orientation of R&D

Across the countries analysed in this study, tax incentives do not condition the provision of support other than as implied by pre-defined rules and leave the choice of how to conduct and pursue R&D programmes in the hands of the private sector. As tax incentives may be more effective in inducing some types of R&D than in inducing others, they may affect not only the volume but also the type of R&D undertaken by firms.

Table 6. R&D price elasticity by orientation of R&D

Dependent variable: log expenditure on	Research (basic and applied)	Experimental development
	(1)	(2)
log BIndexSyn	-0.402***	-0.758***
	(0.104)	(0.099)
Observations	5808	5808
Countries	16	16

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects, industry-year fixed effects and size class-year fixed effects. The analysis covers 16 OECD countries: Australia, Austria, Belgium, Chile, the Czech Republic, France, Germany, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

This can be explored by estimating the price elasticity for research (sum of basic[32] and applied research) versus that for experimental development (**Table 6**). The estimated price elasticity for research (-0.40) is around half the size of the one estimated for experimental development (-0.76), suggesting that tax incentives induce firms more strongly to invest in experimental development than basic and applied research.

3.2.2. Impact mechanisms for R&D tax incentives

The results presented so far show that business R&D expenditure responds positively to reductions in the user cost of R&D induced by R&D tax incentives. This section aims to shed light on the mechanisms underlying this response. It examines whether the observed effects are attributable to real increases in R&D expenditure and employment (quantity effects) or increases in R&D wages (price effects) and whether those effects arise due to increases in R&D expenditure among existing R&D performers (intensive margin) or also due to new firms starting to invest into R&D (extensive margin).

Price vs. quantity effects

The increase in R&D expenditure as a response to tax subsidies could partially reflect an increase in researcher wages rather than R&D employment.[33] The results presented in **Table 7** provide evidence on this point, distinguishing between employment in headcounts (columns 2 and 3) and full-time-equivalents (FTEs; columns 4 and 5). Unfortunately, R&D surveys do not collect information on individual wages but on total labour costs. A measure of implied R&D unit labour cost has been constructed for defined groups of firms by calculating the mean R&D labour expenditure to R&D employment (headcounts or full-time-equivalents) ratio across firms in a given group (see **Table 2**).

Table 7. R&D employment and implied R&D wages

		Headcount		Full-time-equivalents	
Dependent variable: log R&D outcome	R&D labour expenditure	R&D Employment	Implied R&D unit labour cost	R&D hours worked	Implied R&D unit labour cost
	(1)	(2)	(3)	(4)	(5)
log BIndexSyn	-0.361***	-0.740***	0.282***	-0.398***	0.056
	(0.071)	(0.074)	(0.051)	(0.068)	(0.051)
Observations	4324	4324	4324	4324	4324
Countries	14	14	14	14	14

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects, industry-year fixed effects and size class-year fixed effects. The analysis covers 14 OECD countries: Austria, Belgium, Chile, the Czech Republic, France, Germany, Hungary Israel, Italy, the Netherlands, New Zealand, Norway, Portugal and Sweden.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

The estimated user cost elasticities suggest that increases in R&D labour expenditure are driven by increases in the number of R&D employees and R&D hours worked[34] (columns 2 and 4) rather than increases in R&D unit labour costs (columns 3 and 5). [35] The increase in R&D employment is stronger in headcounts (column 2) than in FTEs devoted to R&D (column 4), indicating that the additional R&D human resources spend on average less time on R&D than R&D employees did previously. While this may indicate that firms hire new staff to work on R&D on a part time basis, it is also possible that they re-assign existing staff's time away from other activities to work on R&D projects. The latter could be considered as potentially indicative of relabelling activity, casting some doubts on the additionality of the effects. Having said that, as noted earlier, R&D tax incentives may explicitly pursue the re-orientation and formalisation of existing innovation active within firms so that it can be properly considered as R&D and have more substantive and sustained impacts. A stricter control of time spent on R&D could also partly explain the stronger effect found for headcounts vs. FTE. Belgium authorities, for instance, increased controls on researcher timesheets following the introduction of a partial payroll withholding tax exemption in 2005.

The average implied R&D unit labour costs in headcounts (column 3) seem to *decline* as the B-index decreases and implied R&D tax subsidy rates increase. As no such decline is observed in terms of full-time equivalents (column 5), the decline in unit labour costs in headcounts can be explained by the previous observation that the additional R&D workers devote, on average, fewer hours to R&D.

Effects at the intensive and the extensive margins

R&D expenditure may increase in response to R&D tax incentives both because existing R&D performers increase their R&D expenditure (intensive margin) and because extra firms start performing R&D (extensive margin). Estimating R&D responses at the extensive margin – the number of R&D performers and entry into R&D performance – relies on the availability of representative data on the population of R&D performers over time. As large firms tend to perform R&D more regularly, firms that start to invest in R&D are likely to be small. They might not be tracked with certainty in business R&D surveys, so the estimates of the extensive margin should be interpreted with some caution.

The results presented in **Table 8** suggest that effects at both the extensive and intensive margin are important and should be taken into account. A reduction in the user cost of R&D is strongly associated with a marked increase in the number of firms performing R&D

(column 1). This is in line with firm-level evidence for Norway (Haegeland and Møen, 2007), which indicates a positive effect of R&D tax credits in Norway on the probability of starting and continuing to perform R&D.

Table 8. Intensive and extensive margins of R&D response to changes in the user cost

	Extensive margin (changes in firms performing R&D)				Intensive margin (changes within R&D performing firms)		
Dependent variable:	log number of R&D performers	2-year change in log number of R&D performers			2-year change in log intramural R&D expenditure		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log BIndexSyn	-0.707***						
	(0.056)						
2-year growth in BIndexSyn		-0.261***	-0.213***		-0.200***	-0.193***	
		(0.039)	(0.047)		(0.042)	(0.047)	
d2logBIndexSyn4				-0.218*** (0.047)			-0.204*** (0.048)
Observations	6822	4535	2278	2278	4535	2278	2278
Countries	18	16	12	12	16	12	12

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for country-industry-size class fixed effects, industry-year fixed effects, size class-year fixed effects and either industry-level log value added lagged by 2 years (column 1) or 2-year log change in the value added (columns 2-7). The analysis covers 18 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom. Results in columns 2 and 5 are based on observations with non-missing 2-year log change in BIndexSyn and do not include Canada and Hungary. Results in columns 3, 4, 6 and 7 are based on observations with non-missing values of d2logBIndexSyn4 and additionally do not include Chile, Italy, the Netherlands and Sweden.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Similarly, 2-year changes in the number of R&D performers are positively associated with reductions in B-Index over a two-year time span (columns 2-4). At the same time, within-firm 2-year growth rates of R&D expenditure are also positively correlated with reductions in the B-Index (columns 5 and 7), with the estimated coefficient being of similar magnitude as for the 2-year changes in the number of R&D performers. Taken together, these results imply that both the extensive and the intensive margin contribute to the overall elasticity of R&D with respect to its user cost.[36]

The results in **Table 8** are also reassuring concerning the exogeneity of the synthetic B-Index, as it purports to capture the variation in tax incentive design rather than firm-level R&D performance. Columns 3 and 6 use 2-year log changes in the synthetic B-Index, which serves as the baseline explanatory variable in this section. These changes reflect changes in the R&D tax incentive design between years t and t-2, but they also reflect changes in firms' R&D performance between t-2 and t-4. Columns 4 and 7 instead contain estimates based on ds2logBIndexSyn4 – the synthetic change in the B-Index that captures exclusively changes in design, keeping R&D performance fixed at the level of year t-4. Both approaches lead to virtually identical results, strongly indicating that the synthetic B-Index can be considered as exogenous and, thus, identifies causal effects.

3.2.3. Heterogeneous effects

An important advantage of the micro-aggregated approach adopted in this study is that it allows examining how the price elasticity of R&D varies across firms with different characteristics. This section presents evidence on the variability of the user cost elasticity of R&D by firm size, R&D intensity and industry.

Differences by firm size and R&D intensity

This study documents a larger responsiveness among smaller firms to R&D tax incentives in a (micro)-aggregate, cross-country context. This result is in line with firm-level studies (see Appelt et al. 2016).[37] **Table 9** presents the results of an estimation that includes interactions of the B-Index with dummy variables for medium-sized and small firms. The estimated coefficient for the non-interacted B-Index can be interpreted as the elasticity for the baseline group of large firms.

Importantly, the heterogeneous effects by firm size depend on the type of R&D cost and whether R&D performance (intramural R&D) or funding (extramural R&D) is the outcome variable of interest. The stronger overall elasticity for medium and small firms is driven by current intramural R&D expenditure. Large firms show elasticities for current intramural expenditure that are small (around -0.2) and not statistically significantly different from zero. In contrast, large firms show strong elasticities for capital intramural expenditure (-0.86) and for extramural expenditure (-0.72) that are not statistically significantly different from those for medium-sized and small firms.

Additional estimations suggest that smaller R&D performers are more responsive to R&D tax incentives independent of their age (**Table C.2**). This analysis is carried out at a more aggregate level of analysis – at country, macro industry (manufacturing, non-manufacturing), firm size and age level – and thus not directly comparable with the results presented in **Table 9**. It indicates that young firms (below five years of age) increase their R&D investment more strongly than old firms (column 2). The estimated elasticity of intramural R&D to the price of R&D is about two times larger for young firms (approx. -1.28) than for old firms (approx. -0.57), although it is statistically significant for both groups. However, when both firm size and age interactions are included in the estimation, only the size-related interaction maintains its statistical significance.

Table 9. R&D price elasticity by firm size

Dependent variable:	Intramural	Labour	Other Current	Capital	Intramural	Extramural
log R&D expenditure	(1)	(2)	(3)	(4)	(5)	(6)
log BIndexSyn	-0.272**	-0.183	-0.196	-0.858***	-0.108	-0.716***
	(0.138)	(0.130)	(0.172)	(0.239)	(0.142)	(0.272)
log BIndexSyn x medium	-0.397**	-0.381**	-0.611**	-0.052	-0.606***	-0.389
	(0.178)	(0.169)	(0.259)	(0.345)	(0.193)	(0.384)
log BIndexSyn x small	-0.771***	-0.739***	-0.920***	-0.236	-0.953***	-0.416
	(0.185)	(0.180)	(0.241)	(0.359)	(0.204)	(0.434)
Observations	6799	5422	5422	5422	4865	4865
Countries	17	15	15	15	16	16

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects, industry-year fixed effects and size class-year fixed effects. Small firms are defined as firms with 10-49 employees and medium firms as firms with 50-249 employees. The analysis covers 17 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom. Results in columns 2-4 are based on observations with non-missing values of intramural R&D by type of cost and do not include Canada and New Zealand. Results in columns 5 and 6 are based on observations with non-missing values of extramural R&D expenditures and do not include Australia.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Smaller firms' greater responsiveness to R&D tax incentives could be related to the relatively low amount of R&D they perform on average, compared to large firms. It is also possible that firms in more R&D-intensive industries systematically differ in their response to tax incentives. The analysis presented in **Table 10** explores these hypotheses. The first specification replicates the results in **Table 9** (column 1), showing greater elasticities for small and medium-sized firms as compared to large firms (column 1).

The next specification (column 2) interacts the B-Index with the log intramural R&D expenditure of an average firm within each country-industry-size cell (measured in the first year when that cell appears in the data) instead of employment size dummies. The interaction term is normalised in such a way that the coefficient on the non-interacted B-Index captures the effect on data cells with the sample mean level of average R&D expenditure (about USD 1 million) and the estimated coefficient on the interaction term corresponds to a 1-standard-deviation change in the average R&D expenditure. The results suggest that firms with greater (initial) R&D expenditure are less responsive to R&D tax incentives. This effect is strong. The estimates indicate that a country-industry-size class cell with average R&D expenditure that is one standard deviation above the sample mean (about USD 5 million) has a user cost elasticity close to zero, while a country-industry-size class cell with average R&D expenditure one standard deviation below the sample mean (about USD 200,000) has a user cost elasticity of over one in absolute terms.

Instead of interacting the B-Index with the initial average level of R&D expenditure as a continuous variable, column 3 interacts it with dummy variables that are defined by partitioning all country-industry-size class cells into three similarly sized groups based on the initial average level of intramural R&D expenditure across firms within each cell. This alternative specification (column 3) again indicates that firms' responsiveness to R&D tax incentives decreases with the initial level of R&D performance. While for firms with a high average level of intramural R&D expenditure (above USD 2 million) the estimated elasticity is not statistically significant from zero, firms with a medium (between USD 400 thousand and USD 2 million), and in particular those with a low (below USD 400 thousand), average level of R&D expenditure are found to respond more strongly to R&D tax incentives. The R&D price elasticities of firms with a medium and low level of R&D expenditure are estimated at -0.71 and -1.34 respectively.

Table 10. R&D price elasticity by firm size and initial R&D intensity

Interaction	By firm size	By average R&D expenditure		By firm size and average R&D expenditure	
Dependent variable:	Intramural				
log R&D expenditure	(1)	(2)	(3)	(4)	(5)
log BIndexSyn	-0.272**	-0.588***	0.107	-0.839***	0.069
	(0.138)	(0.068)	(0.125)	(0.154)	(0.133)
log BIndexSyn x medium	-0.397**			0.381*	0.149
	(0.178)			(0.203)	(0.204)
log BIndexSyn x small	-0.771***			0.398*	0.137
	(0.185)			(0.225)	(0.230)
log BIndexSyn x initial average R&D		0.628***		0.744***	
		(0.071)		(0.094)	
log BIndexSyn x medium initial average R&D			-0.707***		-0.769***
			(0.169)		(0.204)
log BIndexSyn x low initial average R&D			-1.340***		-1.434***
			(0.170)		(0.221)
Observations	6799	6799	6799	6799	6799
Countries	17	17	17	17	17

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects, industry-year fixed effects and size class-year fixed effects. Small firms are defined as firms with 10-49 employees and medium firms as firms with 50-249 employees. Initial average R&D is defined as average intramural R&D expenditure by firms in given country-industry-size class cell in the first year of observation; it is classified medium if it is between USD 400 000 and 2 000 000 and low if it is below USD 400 000. The analysis covers 17 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

When the interactions of the B-Index with firm size dummies and initial average R&D expenditure (level specification) are included together (column 4), the estimated interactions with size dummies actually turn positive (indicating *smaller* elasticities for medium and small firms), while the interaction with initial average R&D expenditure retains high statistical significance and slightly increases in size. The results are similar when dummies for initial average R&D are used instead of a continuous variable (column 5), except that in this case the interactions of the B-Index with firm size dummies are no longer statistically significant.

This result is important. It suggests that firms' responsiveness to R&D tax incentives is determined by firms' initial level of R&D expenditure – firms that perform relatively little R&D in the absence of tax incentives increase their R&D expenditure most (in proportional terms). Put differently, the observed variation in the price elasticity of R&D across firms of different size seems to reflect firms' level of R&D performance rather than firm size as such. The greater user cost elasticity – and, by implication, greater input additionality (**Table 12**) – estimated for smaller firms, is a consequence of the fact that small firms perform less R&D on average.

Differences by industry sector

Firms' responsiveness to R&D tax incentives could also vary across industry sectors. **Table 11** presents estimates of the price elasticity of intramural R&D by industry, distinguishing between six types of industries: (1) manufacturing vs. non-manufacturing, (2) services vs. non-services, (3) medium and high R&D-intensive vs. other industries, (4) high R&D-intensive vs. other industries, (5) highly digital intensive vs. less digital-intensive industries, and (6) knowledge-intensive services vs. other parts of the economy.

Industries levels of R&D intensity are defined following the classification by Galindo-Rueda and Verger (2016),[38] and highly digital-intensive industries are defined based on the new OECD classification proposed by Calvino et al. (2018).[39] Non-financial market services are grouped into knowledge-intensive services (KIS) and less knowledge-intensive services (LKIS) following the Eurostat classification of knowledge-intensive services, based on the share of tertiary educated persons at the NACE Rev.2 2-digit level.[40]

The results presented in **Table 11** suggest that the user cost elasticities of firms in manufacturing (column 1), services (column 2), medium to high R&D-intensive sectors (column 3), digital-intensive industries (column 5), or knowledge-intensive services (column 6) do not differ from those of firms in other parts of the economy. In high R&D-intensive sectors (Pharmaceuticals, Computer manufacturing, R&D services), however, this elasticity (column 4) appears to be significantly lower than in non-high R&D-intensive sectors. The interaction term for the high R&D-intensive sectors (0.55) almost completely offsets the non-interacted effect (-0.76), indicating that firms in high R&D-intensive sectors respond little to R&D tax incentives. This result is consistent with the earlier finding (**Table 10**) that firms with a high initial level of R&D expenditure have low user-cost elasticities.

The results of the meta-analysis by Castellaci and Lie (2015) indicate substantially stronger effects of tax incentives in services industries, unlike this report, but are in line with the non-differential and significantly lower effects found for manufacturing and high-tech sectors respectively. Acconcia and Cantabene (2018), examining the effect of the 2009 R&D tax credit related stimulus programme in Italy, also find a lower effect for high-tech firms. By contrast, Freitas et al. (2017) find tax incentives to have *stronger* input and output additionality effects on firms in industries with a strong R&D orientation.

Table 11. R&D price elasticity by industry

Interaction	Manufacturing	Services	Medium & High-R&D intensive	High R&D intensive	Digital-intensive	Knowledge-intensive
Dependent variable:	Intramural					
log R&D expenditure	(1)	(2)	(3)	(4)	(5)	(6)
log BIndexSyn	-0.532***	-0.741***	-0.714***	-0.735***	-0.650***	-0.695***
	(0.124)	(0.087)	(0.101)	(0.081)	(0.093)	(0.084)
log BIndexSyn x manufacturing	-0.222					
	(0.155)					
log BIndexSyn x services		0.250				
		(0.166)				
log BIndexSyn x medium & high-R&D intensive			0.130			
			(0.146)			
log BIndexSyn x high-R&D intensive				0.544***		
				(0.176)		
log BIndexSyn x digital-intensive					-0.043	
					(0.154)	
log BIndexSyn x knowledge-intensive						0.156
						(0.184)
Observations	6822	6822	6822	6822	6822	6822
Countries	18	18	18	18	18	18

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects, industry-year fixed effects and size class-year fixed effects. The analysis covers 18 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden and the United Kingdom.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

3.2.4. R&D input additionality

Incrementality ratios can be derived based on the estimated elasticities of business R&D to the user cost (B-Index). These ratios indicate the extent to which R&D support policies are effective in generating additional R&D expenditure beyond the counterfactual level that would have been observed in their absence. **Table 12** presents the incrementality ratios derived for R&D tax incentives based on the main elasticity estimates presented in the previous subsections.[41] Reported are *gross* incrementality ratios. As previously noted, gross incrementality ratios of less than 1 suggest a crowding out of privately-funded R&D, while those larger than 1 imply crowding-in of privately funded R&D. An incrementality ratio of 1 implies a neutral effect where one unit of support translates into one unit of R&D.

Table 12. R&D input additionality

	R&D input additionality	Price elasticity estimate	
	Incrementality ratio (gross)	Coefficient	Observations
Tax incentives			
Baseline			
All firms	**0.996** (0.831, 1.152)	-0.665	6822
All firms (accounting For R&D tax support use)	**1.409** (0.997, 1.785)	-1.009	3118
By firm size			
Large (250 or more employees)	**0.441** (0.074, 0.776)	-0.272	6799
Medium (50-249 employees)	**0.999** (0.745, 1.236)	-0.669	6799
Small (10-49 employees)	**1.438** (1.204, 1.653)	-1.0438	6799
By initial level of R&D of average firm			
Low (< USD 400 000)	**1.726** (1.442, 1.980)	-1.340	6799
Medium (USD 400 000 - 2 000 000)	**1.047** (0.673, 1.384)	-0.707	6799
High (> USD 2 000 000)	**-0.187** (-0.569, 0.167)	0.107	6799
By industry			
Non high R&D-intensive	**1.087** (0.913, 1.251)	-0.735	6799
High R&D-intensive	**0.307** (-0.111, 0.690)	-0.191	6799

Note: The table reports incrementality ratios implied by the estimate elasticities of intramural R&D expenditure with respect to $BIndex_t^{syn2}$, as reported in **Table 4**, **Table 9**, **Table 10**, and **Table 11**. The derivation of the incrementality ratios is described in **Section 3.1.2**. Lower and upper limits of the 90% confidence interval are reported in parentheses.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

The baseline specification yields an incrementality ratio of close to 1, implying that one unit of R&D tax subsidy translates into around one unit of R&D investment by business. The 90% confidence interval (CI90) for the incrementality ratio is 0.83-1.15.[42] When R&D price elasticities are estimated based on the tax-based version of the B-Index (BIndexTax), which accounts for the actual use of R&D tax incentives, the incrementality ratio increases to 1.41 (CI90 1.00-1.79). R&D input elasticity estimates by firm size indicate a crowding out effect in the case of large firms (IR 0.44, CI90.07-0.78), a neutral effect for medium-sized firms (IR 1.00, CI90 0.75-1.24) and crowding in in the case of small firms (IR 1.44, CI90 1.20-1.65). This effect is also attributable to the initial level of R&D performance rather than firm size as such. For groups with a high initial level of intramural R&D expenditure on average (above USD 2 million), the gross incrementality ratio is estimated at -0.19 (crowding out), while it is 1.05 (neutral) and 1.73 (crowding in) for firm groups with a medium (USD 400 000 - USD 2 million) and low (below USD 400 000) level of average intramural R&D expenditure. Similarly, for firms in high R&D-intensive industries (Pharmaceuticals, Computer manufacturing, Scientific R&D), a crowding out effect is estimated (IR 0.31), whereas a neutral effect is found for firms in less R&D intensive sectors (IR 1.09).

3.3. The role of R&D tax incentives in the policy mix

An important policy question is how the effectiveness of R&D tax incentives compares to that of alternative policy tools and how the various policy tools available to policymakers interact with each other. This section presents the results of an exploratory analysis on the role of policy mix, focusing on two additional policy tools – corporate income taxation and direct R&D funding.

3.3.1. Corporate income taxation

Table 13 presents evidence on the role of corporate income taxation, both as a control and as an economic policy variable of independent interest. Column 1 replicates the baseline result for the B-Index, reporting a user cost elasticity of around -0.7. Specification 2, where the statutory combined (central and sub-central) CIT rate enters as sole policy variable, shows a negative relationship between R&D expenditure and the CIT rate. When both policy variables enter the estimation (column 3), the estimated coefficient on the B-Index increases in magnitude. The elasticity with respect to the synthetic B-Index and semi-elasticity with respect to the CIT rate are estimated at -0.77 and -3.08 respectively: a 1-percentage-point (PP)-reduction in the CIT rate corresponds to an increase of R&D investment by around 3.1%.[43]

Table 13. R&D price elasticity – role of corporate income taxation

Policy variable	B-Index	CIT	Both	Both + Interaction
Dependent variable:	Intramural R&D			
log R&D expenditure	(1)	(2)	(3)	(4)
log BIndexSyn	-0.665***		-0.765***	-0.774***
	(0.163)		(0.147)	(0.144)
CIT		-2.430**	-3.082***	-3.156***
		(0.936)	(0.824)	(0.836)
log BIndexSyn x CIT				0.687
				(1.056)
Observations	6822	6822	6822	6822
Countries	18	18	18	18

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-size level (clustering at the country level makes the CIT rate in column 2 significant only at the 10% level). Targeted CIT rates apply to SMEs in 6 out of 20 countries (Australia, Canada, Hungary, Japan, the Netherlands and Portugal) in one or more years. Small firms are defined as firms with 10-49 employees and medium firms as firms with 50-249 employees. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects, industry-year fixed effects and size class-year fixed effects. The analysis covers 18 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden and the United Kingdom.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

This result contrasts with the lack of a negative effect found in the macroeconomic analysis in Appelt et al. (2019), where the CIT rate has been found not to be a significant macro driver of business R&D investment. This difference in meso and macro level results may be attributable to the variation in CIT rates among firms of different size which only this meso-level analysis can account for. The analysis at the country-industry-size class level allows modelling targeted CIT rates that apply to SMEs in some countries, and the use of matched administrative data facilitates the application of country-specific SME definitions at the firm level where these differ from the standard employment-based SME definitions (e.g. Canada and Japan).

The interaction between the two policy indicators (column 4) is not statistically different from zero. In other words, the effect of R&D tax incentives does not seem to vary with the rate of corporate income taxation. While one might expect R&D tax subsidies to be most effective when firms are subject to a high CIT rate, this interaction effect may already be captured by the tax support variable which accounts for the CIT rate (see **Box 2.1**). Furthermore, it is important to fully take into account the extent to which firms in different cells can claim the notional tax subsidy, which requires using data on actual tax support received. This is left for future work when it is possible, for a larger group of countries, to link profitability or tax support information.

While the results in this paper suggest that a reduction in corporate income taxes may stimulate R&D investment, this does not necessarily mean that CIT reductions are a cost-efficient way of encouraging R&D or other forms of investment. In particular, the non-targeted nature of such support can be expected to lead to substantial deadweight costs due to the support going companies that do not invest in R&D regardless. To investigate this, **Table 14** presents the *gross* incrementality ratios derived from the elasticity estimates (average effect across all firms) presented in **Table 13**. The *gross* incrementality ratio estimated for R&D tax incentives – a ratio of around 1 – is in line with the initial estimates obtained based on the analysis of R&D tax incentives (**Table 12**). For CIT reductions, the *gross* incrementality ratio is estimated at 0.24 (90% confidence interval 0.10-0.38), suggesting that one dollar of foregone tax revenue is associated with a 0.24 dollar increase in R&D expenditure. If reducing CIT rates is evaluated purely as an R&D support policy, the results indicate that it is less efficient than innovation policy tools that are specifically targeted towards R&D investment.

Table 14. R&D input additionality of CIT reductions

	R&D input additionality	R&D price elasticity	
	Incrementality ratio (gross)	Coefficient	Observations
Analysis of R&D support policy mix (Section 3.3.1)			
R&D tax incentives (all firms)	**1.124** (0.702, 1.496)	-0.765	6822
CIT reductions	**0.241** (0.103, 0.379)	-3.082	6822

Note: The table reports incrementality ratios implied by the estimated elasticities and semi-elasticities of own-funded intramural R&D expenditure with respect to BIndexSyn and statutory CIT rates respectively (**Table 13**, column 3). The derivation of the incrementality ratios is described in **Section 3.1.2**. Lower and upper limits of the 90% confidence interval are reported in parentheses.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

The main purpose of the analysis on CIT rates is to provide an additional control in the investigation of R&D support mechanisms, with the conclusion that the results are not driven by underlying changes in CIT rates. It is beyond the scope of this study to explore the R&D impact mechanisms of CIT rate changes. These are likely to exhibit more complex dynamics than incentives that impact on the cost of R&D. One way in which a reduction in CIT rates could affect R&D investment is through expected higher future net returns from productive R&D investments, but this would require firms to expect CIT rate cuts to be maintained over the R&D project cycle until they deliver revenues to the firm. This raises the question of whether the estimates may be instead identifying the impact of CIT rates on the ability of firms to finance R&D, for example in the presence of imperfections in financial markets for risky investments which make liquidity an important driver of investment, especially for smaller firms. The identification of the relevant CIT rates is also hampered by the fact that multinational enterprises, which account for most R&D, are operating in different jurisdictions and in their case, domestic reference rates may exhibit considerable measurement error.

3.3.2. Direct funding of business R&D

The results on the role of direct funding of business R&D are provided in **Table 15**. To address the potential endogeneity of direct support (**Section 3.1**), own-funded intramural R&D expenditure is used as outcome variable (i.e. intramural R&D expenditure net of direct funding and other external sources of R&D funding) and a two-year lag of the direct funding is used in the estimation.

The first estimation (column 1) includes only the synthetic B-Index as a policy variable. The user cost elasticity, estimated at around – 0.72, is similar to the one found in the initial analysis on the price elasticity of intramural R&D based on the data for the full sample of 18 countries (**Table 4,** column 5). The elasticity of own-funded intramural R&D with respect to direct funding (column 2) is 0.036, implying that a 10% increase in direct funding corresponds to an R&D increase of around 0.36%. The elasticity of tax support remains virtually unchanged when effects of both types of support are estimated simultaneously, while the elasticity for direct support decreases slightly to 0.031 (column 3).

Table 15. R&D price elasticity by R&D support policy instrument

Policy variable	Tax	Direct	Both	Interaction
Dependent variable:	Own-funded intramural R&D			
log R&D expenditure	(1)	(2)	(3)	(5)
log BIndexSyn	-0.720***		-0.703***	-0.678***
	(0.083)		(0.082)	(0.082)
log Direct Funding (2-year lag)		0.036***	0.031***	0.030***
		(0.009)	(0.009)	(0.009)
log BIndexSyn x log (Direct				-0.121***
Funding / initial R&D)				(0.045)
Observations	5714	5714	5714	5714
Countries	17	17	17	17

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects, industry-year fixed effects and size class-year fixed effects. The analysis covers 17 OECD countries: Australia, Austria, Belgium, Chile, the Czech Republic, France, Germany, Hungary, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

To test for the complementarity/substitutability between the two types of R&D support, the B-Index is interacted with direct funding (column 5). In calculating this interaction, direct support is normalised by the level of intramural R&D expenditure by firms in a given country-industry-size class group. This ensures that the interaction term captures the intensity of direct support and not just the number of firms in that country-industry-size class cell. The estimated interaction effect (column 4) is negative and strongly statistically significant, implying that the price elasticity of R&D increases with the intensity of direct funding. The estimate suggests that country-industry-size class cells with an intensity of direct funding one standard deviation above the sample mean have a user cost elasticity that is about 0.12 (18%) greater in magnitude than the elasticity of firms in the mean data cell. This preliminary finding suggests that R&D tax incentives and direct funding have a complementary, mutually reinforcing effect.

The existing evidence base on the interaction between direct funding and tax support is comparatively scarce and rather mixed (Appelt et al., 2016). While a number of studies find evidence of a substitution effect (Montmartin and Herrera, 2015; Dumont, 2017), others (Bérubé and Mohnen, 2009; Falk et al., 2009) yield results that speak in favour of a complementarity between R&D tax incentives and direct funding or a neutral effect (Lhuillery et al., 2014). Recent research suggests that the complementarity effect found for R&D tax incentives and direct funding in this cross-country analysis may be mainly driven by small firms (Huergo and Moreno, 2017; Pless, 2019). Using funding rules and policy changes in a quasi-experimental evaluation, Pless (2019), for instance, shows that direct grants and tax credits are complements for small firms but substitutes for larger firms. Huergo and Moreno (2017) yield a similar result for multiple programme participation in Spain (subsidies and R&D loans): multiple schemes are found to have a larger impact on the R&D performance of SMEs, whereas a crowding out effect cannot be ruled out for large firms. An extended analysis would be required to explore this in more detail.

Table 16 presents the *gross* incrementality ratios derived based on the elasticity estimates (average effect across all firms) presented in **Table 15**. The *gross* incrementality ratio estimated for R&D tax incentives – a ratio of around 1 – is in line with the initial estimates obtained based on the full data set (**Table 12**). For direct funding, the *gross* incrementality ratio is estimated at 1.37 (90% confidence interval 1.19-1.55), suggesting that direct funding induces some additional R&D spending by firms beyond the amount of support provided.

Table 16. R&D input additionality by policy instrument

	R&D input additionality	R&D price elasticity	
	Incrementality ratio (gross)	Coefficient	Observations
Analysis of R&D support policy mix (Section 3.3)			
R&D tax incentives (all firms)	**1.072** (0.891, 1.242)	-0.719	5692
Direct funding (accounting for receipt of direct funding, 2-year lag)	**1.373** (1.193, 1.554)	0.031	5714
Analysis of R&D tax incentives (Section 3.2)			
R&D tax incentives (accounting for R&D tax incentive uptake)	**1.409** (0.997, 1.785)	-1.009	3118

Note: The table reports incrementality ratios implied by the estimated elasticities of own-funded intramural R&D expenditure with respect to BIndexSyn and direct funding of BERD (**Table 15**, column 4). It also includes the incrementality ratios implied by the estimated elasticity of intramural R&D expenditure with respect to BIndexTax (**Table 12**). The derivation of the incrementality ratios is described in **Section 3.1.2**. Lower and upper limits of the 90% confidence interval are reported in parentheses.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

While these results could suggest that direct support measures have on average a larger R&D input additionality than R&D tax incentives, it is important to keep in mind that the estimation based on BIndexSyn yields an "intention to treat" effect (see **Section 3.1.1**) which might understate the actual price elasticity of R&D and input additionality of R&D tax incentives. BIndexSyn reflects the generosity of R&D tax incentives in account of firms' characteristics but it does not reflect whether firms actually use R&D tax incentives or not. By contrast, direct funding reflects the incidence of direct funding, i.e. it accounts for firms that receive direct funding and those that do not. This asymmetry in measurement warrants attention. The first part of the analysis that focused solely on R&D tax incentives showed that the incrementality ratio estimated for R&D tax incentives increases to 1.4 once the tax-based version of the *B-Index* (BIndexTax), accounting for the actual uptake of R&D tax incentives, is used in the estimation.

While an estimation based on the refined, tax support based *B-Index* indicator is only possible for the subset of ten countries where matched R&D and tax relief microdata are available, it suggests that the R&D input additionality of R&D tax incentives is likely larger and possibly close to the one of direct funding on average. Note that the greater incrementality ratio when accounting for uptake is not driven by sample composition as regressions using the standard B-Index yield estimates of a similar magnitude in the sample where tax data are available as in the full sample independent of the sample considered (compare columns 9 and 10 in **Table 4**). As additional countries are able to access tax data and those that already do add more years of data, it should be possible to also employ the tax-based version of the B-Index indicator in the combined analysis of R&D tax incentives and direct funding. Further analysis would also be warranted to explore in more detail the variation in the separate and combined effects of R&D tax incentives and direct support measures across different types of firms.

Horses for courses: different instruments for different objectives

An additional question of policy interest is whether direct support measures or R&D tax incentives are more effective in inducing research (basic and applied) vs. experimental development. The exploratory analysis presented in **Table 17** aims to shed light on this point. This estimation differs from the main analysis presented in **Table 15** and may not fully address the possible endogeneity of direct funding. While it adopts again a two-year lag of direct funding, it relies on the breakdown of intramural R&D expenditure by orientation of R&D where the amount of direct funding cannot be directly netted out as more detailed data on government-financed BERD by orientation of R&D are not available.

Table 17. The link of R&D orientation with tax and direct R&D support instruments

Dependent variable: log R&D expenditure	Research (basic and applied)	Experimental development
	(1)	(2)
log BIndexSyn	-0.391***	-0.749***
	(0.107)	(0.102)
log Direct Funding	0.042***	0.021*
(2-year lag)	(0.010)	(0.011)
Observations	5324	5324
Countries	15	15

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects, industry-year fixed effects and size class-year fixed effects. The analysis covers 15 OECD countries: Australia, Austria, Belgium, Chile, the Czech Republic, France, Germany, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, and the United Kingdom.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

That said, this estimation confirms the earlier finding (**Table 6**) that R&D tax incentives represent inducements for firms to invest in experimental development rather than in research. In contrast, direct funding represents a relatively bigger inducement for research compared to experimental development. The elasticity of experimental development (-0.75) to changes in the user cost of R&D is about twice as large as the one estimated for research (-0.39), while the elasticity of experimental development to direct funding (0.021) is only half as large as the elasticity of research to direct funding (0.042). However, it is important to note that the data do not allow determining what share of direct funding goes to experimental development as opposed to basic and applied research. The estimates, therefore, capture the elasticity of experimental development (or basic and applied research) with respect to the *combined* direct funding for both types of project. As a result, the lower elasticity in the case of experimental development may be due to a lower additionality of direct funding for experimental development projects, but it may also be due to a small share of direct funding flowing to such projects. Furthermore, the composition of direct funding (R&D grants and government procurement of R&D services) varies across countries, making it difficult to disentangle the actual effect of direct support measures based on the aggregate information on government-financed BERD at hand.

R&D tax incentives appear to be the more suitable policy tool to encourage experimental development activities in the business sector, while direct government funding seems to be comparatively more effective at promoting research that, while still oriented towards ultimate application, is further away from being ready for implementation in the market. This finding again hints at the complementary nature of direct and indirect support mechanisms.

Chapter 4. Country-specific analyses based on firm-level data

The micro-aggregated impact analysis presented in the previous section has documented the input additionality effects that R&D tax incentives (and direct support) have *on average* across the different countries considered in the analysis. This section represents an attempt to look inside these averages and understand how the effects vary across countries. This analysis is undertaken at the level of firms within individual countries. Regressions that explain the level of R&D within firms in response to changes in policy variables are run in a distributed way directly on the microdata, separately within each country, based on a harmonised methodology. This, in principle, ensures the cross-country comparability of the estimated coefficients.

The firm-level analysis relies on difference-in-differences ("Diff-in-diff") estimations which exploit information on policy uptake and policy changes. The analysis based on policy uptake is implemented for R&D tax incentives and direct funding. The analysis based on policy changes is confined to R&D tax incentives and exploits exogenous changes in the design of R&D tax incentives which apply only to certain firms or affect some firms more than others within a country. This "quasi-experimental" approach helps corroborate the more general estimates derived based on the policy uptake.

4.1. Methodology

This section describes the two estimation approaches adopted in the firm level impact analysis: a difference-in-differences matching estimation based on policy uptake – adopted in the case of R&D tax incentives and direct funding – and a difference-in-differences estimation based on specific policy changes in the availability or design of R&D tax incentives. It then explains how input additionality estimates can be derived from the estimated treatment effects.

4.1.1. Estimation strategy

Distributed regressions are run directly on firm-level data in each participating country and make use of the within-country variation in the R&D and tax relief data across firms and over time. As with the micro-aggregated analysis, the focus is on input additionality. The primary outcome variable is the combined value of intramural and extramural R&D expenditure of each firm.[44]

The aim is to estimate the effect of tax incentives and direct support by assessing how the R&D performance of firms in the presence of support differs from the level of R&D that would be observed in its absence. The key challenge is that firms' R&D performance can be correlated with government R&D support for many reasons and not only because such support causes firms to increase their R&D expenditure. For example, when the value of R&D tax relief is calculated as a fixed percentage of each firm's R&D expenditure, firms performing more R&D will receive more tax relief even if tax subsidies have an effect on their R&D investments.[45] This creates a positive correlation between the level R&D performance and R&D tax support that reflects in part the fact that R&D expenditure increases the amount of R&D tax subsidies received rather than the other way round.

Two distinct approaches are adopted in this paper to overcome this challenge and estimate the effect of tax support on R&D performance. The first approach compares firms that start using R&D tax incentives or receiving direct support to other similar firms that do not. The second approach exploits specific R&D tax incentive policy changes that increase the marginal tax subsidy rates for some firms while keeping them fixed for others.

Difference-in-differences based on policy uptake

Although R&D tax incentives represent a market-based, non-discretionary policy tool that is, in principle, available to all R&D performing firms, not all eligible R&D performing firms actually use them. Some firms may not be aware of the availability of R&D tax relief provisions, others may be deterred by administration and compliance costs (reporting requirements, audits etc.), and yet others may rely on other forms of government support and not require additional funding. Across the 10 countries for which matched R&D survey and tax relief microdata are available, only about half of R&D performing firms (featuring in R&D surveys) receive R&D tax relief on average.

Compared to R&D tax incentives, direct support implies a higher degree of discretion on the part of government authorities which has implications for the impact estimation. R&D grants, for example, are subject to an at least dual selection process. Eligibility may be more constrained and not all potentially eligible firms will decide to apply for an R&D grant; while only a fraction of applicants will actually receive a grant offer, which they may ultimately accept or reject. In the 10 countries considered in the firm-level analysis based on receiving direct support, 19 % of R&D performers benefit from direct R&D funding on average.

This variation in business experience of R&D tax incentives and direct funding support can be used to compare the R&D performance of firms that receive support and those that do not.[46] The estimation approach exploits the idea that government support reduces the marginal cost of R&D only of those firms that receive this support, and consequently should stimulate also only the R&D performance of support recipients. The fundamental estimation challenge is that it is not possible to observe the "counterfactual" – how much R&D the firms receiving R&D tax relief (or direct support) would have performed had they not received this support. Being unable to observe the counterfactual directly, the best alternative is to compare the firms that receive tax relief with that do not but *are otherwise as similar as possible*.

The approach to identify such firms taken here – difference-in-differences with matching – combines two comparisons in an effort to indirectly observe the counterfactual. A within firm-comparison of firms receiving support over time, i.e. prior to and after starting to receive support. This comparison is useful because it removes any time-invariant firm characteristics which could be correlated with receiving tax or direct support. The second comparison compares R&D support recipients ("treated firms") with otherwise similar firms that do not receive such support ("control group").

The treatment and control groups are constructed using a matching procedure. In the case of R&D tax incentives, the treatment group consists of firms that meet two conditions: (i) they start to receive R&D tax relief and continue doing so for at least 3 years; and (ii) they are present in the R&D microdata in the 2 years prior to starting to use the tax incentive and in the 3 years after it.[47] This implies that the analysis is conducted for firms with some level of R&D activity throughout the reference period. This is partly due to the fact that R&D surveys tend to track "known" R&D performers and sample on a random basis companies that may or may not conduct R&D. Instances where companies perform no R&D are excluded from the analysis, as the analysis examines changes in the log of R&D performance. This implies that the micro regressions identify the impact of tax support among continued R&D performers and abstract from changes at the extensive margin. Note also that the treatment group consists of firms that switch from not receiving tax support to receiving it; this means that regular users, who receive public support throughout the sample period, are not included in the analysis.

For each firm treated (starting to use R&D tax relief) in year T, a control group is then constructed consisting of firms that appear in the data in the same years – never receiving tax relief – and belong to the same size class (small, medium, large), macro industry (manufacturing, other), initial R&D performance quintile and R&D grant receipt status. For direct support, the treatment and control groups are constructed in an analogous way with the exception that firm's R&D tax support receipt status is not included as a matching variable due to the restricted availability of such data across participating countries.

This approach, called "coarsened exact matching" (CEM), links firms that show an exact match in terms of all matching variables (e.g. employment size), conditional on these variables being "coarsened" (transformed) to several discreet values (e.g. size classes). Unlike some other matching estimators, CEM is guaranteed to reduce the imbalance between treatment and control groups in terms of the variables used for matching, it automatically restricts data to a common support between the two groups, and it has a number of other desirable statistical properties.[48] At the same time, it is intuitive and easy to implement in the context of a distributed regression analysis.

Once the treatment and control groups are established, the impact of tax incentives (or direct support) is analysed by estimating the following relationship:[49]

$$logY_{it} = \beta_1 Recipient_{it} + \beta_2 \log size_{it} + \gamma_i + \gamma_t + \varepsilon_{it}, \quad (8)$$

where Y_{it} is the outcome (e.g. total intramural and extramural R&D expenditure) for firm i in year t. The dummy variable $Recipient_{it}$ marks firms starting to receive R&D tax relief (or direct support). It is equal to one for the treated firms after they start receiving government support. It is equal to zero for these firms in earlier years, and also in all years for the control firms. β_1 is the estimated effect of public support, which can be interpreted as the average treatment effect on the treated (ATT). The equation controls for firm size (measured by sales when available and employment otherwise), time-invariant characteristics of each firm and year fixed effects. ε_{it} is the residual.[50]

Whether a firm receives direct support is directly retrievable from the R&D survey. In the case of R&D tax incentives, identifying recipients crucially relies on a match of R&D survey and tax relief data. This means that the estimation for tax incentives is only feasible for countries where this match has been performed. For a few countries, firm-level estimates could not be produced due to data limitations.[51] Moreover, firm-level results are only reported when the analysis is based on a sufficiently large number of observations, specifically when both the number of treated firms and the number of control firms are at least 50. At this stage, results based on R&D tax support uptake are reported for 7 countries: Australia, Belgium, the Czech Republic, France, Norway, Portugal and Sweden. Estimates based on receiving direct funding are available for 10 countries: Austria, Canada, the Czech Republic, France, Germany, Italy, Japan, New Zealand, Norway and Portugal.[52] **Table 18** summarises the R&D support policies explored in each country using the first approach. It also states the number of tax (direct) support recipient cohorts – firms starting to receive public support in the same year – that enter the estimation.

Table 18. Policies explored in the diff-in-diff analysis based on policy uptake

	Policy	Time period	Number of cohorts
Australia	R&D tax allowance/tax credit	2005-2016	10
Belgium	Payroll withholding tax exemption, R&D tax credit	2003-2013	5
Czech Republic	R&D tax allowance	2006-2016	9
France	R&D tax credit	2002-2014	11
Norway	R&D tax credit	2001-2015	14
Portugal	R&D tax credit	2007-2012	5
Sweden	Payroll withholding tax credit	2013-2017	2
Austria	Direct funding	2002-2015	7
Canada	Direct funding	2000-2013	13
Czech Republic	Direct funding	2000-2016	16
France	Direct funding	2001-2015	14
Germany	Direct funding	1995-2013	9
Italy	Direct funding	2007-2014	7
Japan	Direct funding	1983-2016	33
New Zealand	Direct funding	2004-2018	7
Norway	Direct funding	1997-2015	16
Portugal	Direct funding	1999-2012	9

Notes: Direct funding includes the provision of R&D grants by government and public procurement of R&D services, but it excludes loans and other financial instruments that are expected to be repaid in full.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Summary statistics for the matched samples used to estimate the effect of R&D tax incentives are shown on a country-by-country basis in **Table 19**. Mean and median employment tend to be similar between treatment and control groups for most countries, especially in view of the relatively large standard deviations. The main exceptions are Belgium and Sweden, where treated firms are larger and perform more R&D. It is also worth noting that the sample firms in France are, on average, much larger than those for other countries and spend more on R&D. For this reason, results for France are reported both for the full sample and for a subsample consisting only of firms in the bottom half of the French R&D distribution. The firms in the sample for Sweden are not particularly large in terms of employment but also spend more on R&D than sample firms for other countries.

Table 19. Summary statistics for diff-in-diff analysis of R&D tax incentives uptake

			Employment			Intramural + Extramural			Direct support
		N	Mean	P50	SD	Mean	P50	SD	Share receiving
AUS	Control	1333	288	40	*1067*	1845	477	*3826*	18%
	Treatment	710	354	38	*1241*	3431	467	*14209*	12%
BEL	Control	386	301	80	*454*	2868	1561	*4597*	23%
	Treatment	195	443	224	*674*	14153	2482	*58605*	21%
CZE	Control	1153	451	179	*631*	1787	228	*3524*	30%
	Treatment	148	482	111	*629*	2879	455	*7116*	30%
FRA	Control	794	2337	351	*15266*	27064	1682	*169285*	30%
	Treatment	567	1854	258	*9924*	20845	1805	*72431*	26%
NOR	Control	341	194	84	*258*	2225	809	*3655*	29%
	Treatment	191	217	70	*341*	2212	594	*4395*	31%
PRT	Control	415	231	83	*434*	928	133	*2063*	17%
	Treatment	78	245	97	*422*	950	174	*1728*	17%
SWE	Control	415	351	89	*738*	8587	2035	*26547*	14%
	Treatment	197	646	76	*2067*	32622	2150	*207155*	14%

Note: For each firm, the table shows summary statistics in the last observed year prior to the treatment of given firm (treated firms) or the matched control firm. R&D expenditure is stated in thousands of 2005 US dollars using PPP exchange rates.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Table 20 presents summary descriptive statistics for the R&D survey samples used in the analysis of direct support. The relatively small numbers of treated firms in many countries (especially Australia and Sweden) reflect the fact that direct support is a more selective tool than R&D tax incentives. The treatment and control firms again look quite similar in most countries.

Difference-in-differences based on policy changes

The second approach in the firm-level impact estimation explores the effects of specific R&D tax policy reforms. It leverages the fact that some policy changes, by design, apply only to certain firms or affect some firms more than others. It is then possible to compare the evolution of R&D expenditure for the affected ("treated") firms and the non-affected ("control") firms and interpret the difference as the effect of the policy. The key assumption is that the R&D expenditure of the two groups of firms would evolve along a similar trajectory in the absence of the policy change.

The approach can be illustrated based on the example of the introduction of the SkateFUNN tax credit in Norway in 2002.[53] Once SkateFUNN was in place, firms could obtain the R&D tax credit for their R&D expenditure, but only intramural expenditure up to NOK 4 million (about USD 400 000) was eligible. For smaller R&D performers, the change reduced the costs of R&D and served as an incentive for additional R&D spending. However, for firms which already before the policy change regularly invested in R&D more than NOK 4 million, this change increased the amount of tax support they received but did not affect the cost of an *additional* ("marginal") unit of R&D investment and so did not necessarily incentivise additional R&D spending among these firms.

Table 20. Summary statistics for diff-in-diff analysis of direct funding

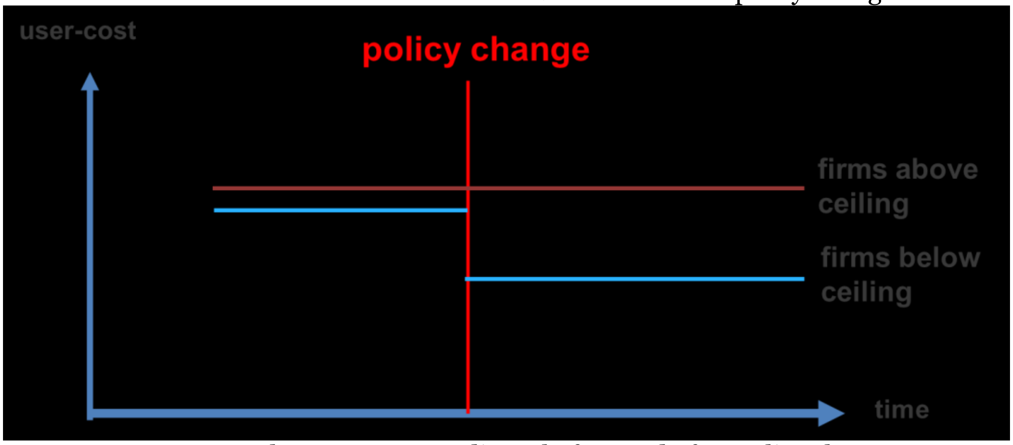
			Employment			Intramural + Extramural			Tax incentives
		N	Mean	P50	SD	Mean	P50	SD	Share receiving
AUT	Control	2591	210	100	*325*	1549	674	3117	.
	Treatment	329	236	117	*440*	1829	546	4119	.
CAN	Control	.	.	.	.	.	.	.	.
	Treatment	.	.	.	.	.	.	.	.
CZE	Control	1642	545	170	*847*	1357	258	2550	20%
	Treatment	123	395	204	*413*	1388	425	2409	28%
DEU	Control	13387	457	103	*1183*	4784	707	15062	.
	Treatment	1271	974	143	*4478*	12523	1038	52202	.
FRA	Control	5535	601	209	1847	7072	876	26975	74%
	Treatment	289	849	270	1849	8576	1782	20351	83%
ITA	Control	6608	414	83	1923	3207	513	10322	4%
	Treatment	117	449	91	1116	4521	1494	13988	3%
JPN	Control	35089	1389	288	*3448*	20073	1152	134361	.
	Treatment	476	2021	641	*2815*	18055	1832	34758	.
NOR	Control	955	194	93	*299*	1707	657	4322	37%
	Treatment	90	180	111	*242*	1209	812	1505	46%
NZL	Control	.	.	.	.	.	.	.	.
	Treatment	63	259	38	489	1484	293	2891	.
PRT	Control	975	261	79	902	1076	183	4090	47%
	Treatment	84	149	53	236	1331	296	2672	65%

Note: For each firm, the table shows summary statistics in the last observed year prior to the treatment of given firm (treated firms) or the matched control firm. Missing values are due to data cells blanked for confidentiality reasons and countries without matched tax relief data. R&D expenditure is stated in thousands of 2005 US dollars using PPP exchange rates.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

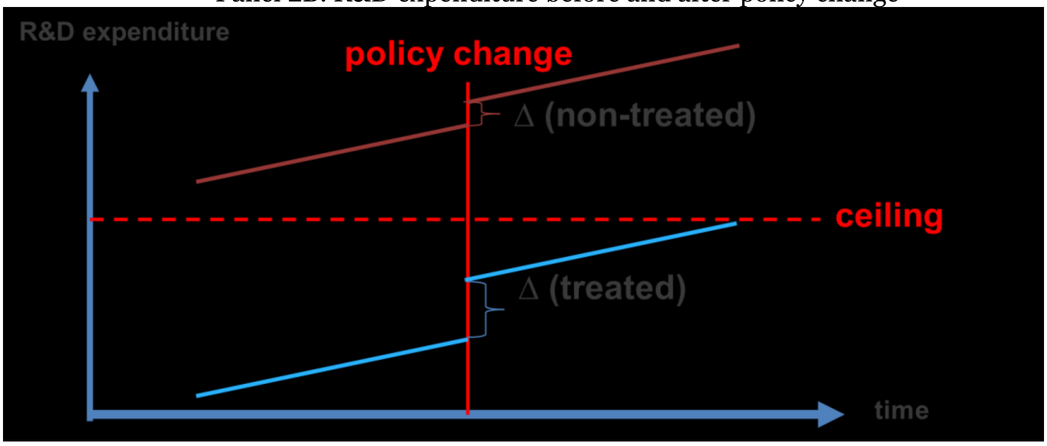
To explore the effect of this change in the R&D tax credit policy of Norway, it is instructive to compare how the R&D performance of firms below and above the new expenditure threshold has evolved around the year 2002 (**Figure 2**).[54] A comparison of the change in R&D expenditure (or other outcome variable) between the pre-reform and post-reform period for firms below and above the ceiling can be used to estimate the effect of the policy change. Prior to the policy change, firms with R&D expenditure below the (post-reform) expenditure ceiling face a similar user cost of capital as firms above that ceiling (Panel A). The policy change makes the user cost fall for firms below the ceiling. By contrast, firms above the ceiling receive a tax subsidy for their R&D expenditure up to the ceiling, but this does not affect their user cost of an additional (marginal) unit of R&D. If firms' R&D investment depends on their user cost, a fall in the user cost of R&D for firms below the ceiling will lead to increased R&D expenditure for these firms (Panel B).

Figure 2. Difference-in-differences approach to estimating impact of R&D tax incentives

Panel 2A. User cost of R&D before and after policy change



Panel 2B. R&D expenditure before and after policy change



Source: OECD microBeRD.

More formally, the following relationship is estimated:

$$logY_{it} = \beta_1 T_i Change_t + \beta_2 \log size_{it} + \gamma_i + \gamma_t + \varepsilon_{it}, \quad (9)$$

where Y_{it} is the outcome (e.g. total R&D expenditure) for firm i in year t. T_i marks the time-invariant treatment variable - a binary dummy equal to one for firms affected by the policy change and zero for others. $Change_t$ is a dummy variable equal to zero prior to the policy change and one in the reform year. β_1 is the impact coefficient of interest. The equation controls for firm size (sales where available and employment otherwise), time-invariant firm characteristics and year fixed effects. ε_{it} is the residual.[55]

The analysis explores eight policy changes (**Table 21**). For Norway and Sweden, the estimation is based on the presence of a ceiling on eligible R&D expenditure, whereby the introduction or extension of a tax incentive encourages additional R&D among firms with R&D below but not those with R&D above this ceiling. The estimation for Austria similarly exploits a ceiling on subcontracted R&D, specifically the fact that the introduction of this ceiling reduced the incentives to fund extramural R&D among firms with extramural R&D above this ceiling but not those operating below the ceiling.

Table 21. Policy changes explored in diff-in-diff analysis

	Year of policy reform	Policy change	Treatment definition	Sample years
Ceiling on qualifying R&D expenditure				
Austria	2005	Ceiling imposed on eligible extramural R&D	Mean extramural R&D in 2002-2004 > EUR 100 000	2004-2010
Norway	2002 (2003)	Volume-based R&D tax credit introduced for SMEs (large firms)	Mean intramural R&D in 1999-2001 < NOK 4 million	1997-2006
Sweden	2014	Introduction of payroll withholding tax credit	Mean R&D tax deduction in 2011-2013 < SEK 2.76 million	2011-2017
Firm size threshold				
Australia	2012	Tax allowance replaced by tax credit with higher rate for SMEs	SME as defined for tax purposes	2008-2016
Japan	2003	Volume-based R&D tax credit extended to large firms	Large firms as defined for tax purposes	2000-2005
Uptake of R&D tax incentives				
Belgium	2005	Payroll withholding tax exemption introduced	Receives tax relief at least once between 2005 and 2007	2001-2007
Chile	2012	Volume-based tax credit extended to intramural R&D	Receives tax relief at least once between 2012 and 2016	2009-2016
France	2008	Hybrid R&D tax credit converted to volume-based R&D tax credit and increase in tax credit rates	Receives tax relief at least once between 2008 and 2012	2004-2012
Italy	2010	Expiration of volume-based R&D tax credit (Law 296/2006), available since 2007	Receives tax relief for qualifying R&D incurred in all years 2007-2009	2007-2013
Norway	2002 (2003)	Volume-based R&D tax credit introduced for SMEs (large firms)	Receives tax relief at least once between 2002 and 2006	1997-2006
Sweden	2014	Introduction of payroll withholding tax credit	Receives tax relief at least once between 2014 and 2017	2011-2017

Note: Australia: SMEs are defined for tax purposes as firms which are not controlled by exempt entities and have turnover of less than AUD 20 million. Due to data limitation, only the turnover-based condition is applied here. Austria: Introduction of the ceiling reduced the marginal subsidy for the treated firms (those with R&D expenditure above the ceiling prior to the policy change), so it can be expected to *reduce* R&D performance among these firms. Japan: SMEs are defined for tax purposes as firms with 100 million yen or less of stated capital or firms controlled by an enterprise meeting the capital condition. Due to data limitation, only each firm's own stated capital is used here to define SMEs. Norway: Estimation takes into account that large firms became eligible for the tax credit only in 2003. Norway applies separate ceilings on intramural, extramural and total R&D expenditure. The ceiling on intramural expenditure is used here to produce baseline estimates, and robustness of the results to instead using the ceiling on the total R&D expenditure is tested.
Source: OECD R&D Tax Incentives Database, http://oe.cd/rdtax, June 2020.

In other cases, policy changes that exclusively apply to firms of different size are exploited. For example, in Japan, a policy change in 2003 made the, optional but more generous, volume-based tax credit also available to large firms (as defined for tax purposes) which beforehand could only apply for the incremental R&D tax credit. The differential treatment of firms of different size is also leveraged in Australia, where a policy change in 2012 (introduction of the R&D Tax Incentive, replacing the former R&D tax concession schemes) increased significantly the marginal R&D subsidy rates of SMEs but did not have a material impact on those of large firms.

Whenever tax incentives do not have any design features that imply differences in treatment for specific types of firms, information on the uptake of R&D tax incentives following (or prior to) the policy change is exploited. In other words, a comparison is made between the evolution of R&D expenditure of firms that receive R&D tax incentive support after (or before) the policy change and those that do not.[56] Policy reforms where treated firm are defined by receiving tax support *after* the policy change include the introduction of a partial payroll withholding tax exemption in Belgium in 2005,[57] the extension of the volume-based tax credit in Chile, previously only applicable to extramural R&D expenditure, to intramural R&D and the conversion of the previously hybrid R&D tax credit in France to an entirely volume-based tax credit in 2008. This definition of treatment group is also applied for Norway and Sweden (where an alternative treatment group definition based on ceilings are available) to allow a comparison of estimates obtained with different treatment group definitions when studying the same policy change. For Italy, in contrast, the analysis explores the expiration of the volume-based R&D tax credit in 2010, which had been available in Italy since 2007. Treated firms are defined as those that incurred qualifying R&D expenditure and were eligible to receive R&D tax support in the years 2007-2009, i.e. *before* the policy change.[58]

Table 22. Summary statistics for diff-in-diff analysis of R&D tax incentive policy changes

				Emp			IntraExt			Direct support
			N	Mean	Median	SD	Mean	Median	SD	Share receiving
AUS	Control	Large	459	1654	682	3969	11853	3322	39919	5%
	Treatment	SME	1053	63	40	58	1194	534	2417	6%
AUT	Control	Above ceiling	158	330	.	375	3407	.	5133	51%
	Treatment	Below ceiling	298	247	96	629	868	25	1679	36%
BEL	Control	Non-recipients	282	451	69	2860	1977	428	4701	53%
	Treatment	Recipients	103	696	226	1066	28056	3875	105550	83%
CHL	Control	Non-recipients	286	448	95	1860	657	130	2139	20%
	Treatment	Recipients	74	462	160	759	715	304	1032	34%
FRA	Control	Non-recipients	425	686	66	6786	5911	354	95119	27%
	Treatment	Recipients	2612	616	114	5095	8686	926	53560	33%
ITA	Control	Non-recipients	2594	290	56	1387	2354	382	12316	11%
	Treatment	Recipients	579	135	41	356	1160	380	5753	7%
JPN	Control	SME	853	183	90	588	1964	330	16088	8%
	Treatment	Large	2931	1221	445	3183	23494	2326	131864	14%
NOR	Control	Above ceiling	181	247	.	467	1687	.	1179	33%
	Treatment	Below ceiling	334	106	61	141	203	30	134	25%
	Control	Non-recipients	242	183	95	260	1322	272	3636	20%
	Treatment	Recipients	443	201	62	616	1948	317	8280	35%
SWE	Control	Above ceiling	97	1041	44	1994	18048	3808	14646	20%
	Treatment	Below ceiling	331	236	.	401	1984	1256	3590	13%
	Control	Non-recipients	454	407	161	841	5424	706	22511	10%
	Treatment	Recipients	264	507	66	1831	25044	1898	184229	18%

Note: For each firm, the table shows summary statistics in the last observed year prior to the treatment of given firm (treated firms) or the matched control firm. Missing values are due to data cells blanked for confidentiality reasons. R&D expenditure is stated in thousands of 2005 US dollars using PPP exchange rates.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

In the estimations exploiting firm size thresholds (Australia, Japan) or expenditure ceilings (Austria, Norway, Sweden), the sample is restricted to firms that are in the vicinity of the relevant cut-off points. Firms for which the pre-policy change value of the relevant variable (e.g. stated capital, R&D expenditure) is more than 10 times larger than the given threshold/ceiling are excluded from the analysis. In the estimations based on R&D expenditure ceilings, firms are also dropped from the analysis when their pre-policy change level of R&D expenditure differs from the ceiling by less than a factor of 1.3. In this case, it is unclear if firms so close to the ceiling should be considered as treated or not.

Table 22 presents summary statistics for the firms included in the difference-in-difference analysis based on policy changes. Large differences exist between treatment and control groups, especially when these are defined based on firm size or R&D expenditure. This is to be expected. The key assumption for the estimation is that these differences are not correlated with changes in firms' R&D expenditure following the policy change.

4.1.2. Deriving user cost elasticities and input additionality estimates

The treatment effect estimate obtained from the distributed regressions indicate whether R&D tax incentives and direct funding increase business R&D expenditure, but they cannot be directly compared across countries or different policy tools because the treatment differs across them. For such comparisons, it is necessary to compute user cost elasticities (percent changes in R&D due to a 1% change in the user costs of R&D) or the incrementality ratios (amounts of additional R&D generated by one additional monetary unit of public funding) implied by the estimates.

Difference-in-differences estimation based on policy uptake

In the estimation based on the uptake of R&D tax incentives, the user cost elasticity can be calculated for an average firm profile as follows:

$$e^{TaxUptake} := \frac{ATT}{\log \overline{BIndex}^{recipients} - \log \overline{BIndex}^{non-recipients}}, \qquad (10)$$

where $\overline{BIndex}^{recipients}$ denotes the average B-index of support recipients over the entire estimation sample when the R&D tax incentive is in place, and $\overline{BIndex}^{non-recipients}$ marks the average B-index of firms not using R&D tax incentives over the same period (calculated using the same formula, but setting tax credit or allowance rates to zero). The implied incrementality ratio can be calculated by dividing the additional R&D performed $(\exp(ATT) - 1)$ by the average R&D tax subsidy rate ($\overline{TS\_RD} = \frac{1}{N}\sum_{i=1}^{N}\frac{TS_i}{RD_i}$) across firms:

$$IR^{TaxUptake} := \frac{(\exp(ATT) - 1)}{\overline{TS\_RD}}, \qquad (11)$$

where ATT is the estimated treatment effect, RD_i is firm *i*'s R&D expenditure and TS_i is the R&D tax subsidy received by firm *i*. Note that the firm-level results presented in this report are based on evaluating this formula at the average firm; future work could calculate an incrementality ratio for each firm and then aggregate up these incrementality ratios across firms.

In the estimation based on direct support use, gross incrementality ratios can be similarly obtained as follows:

$$IR^{DirectUptake} := \frac{(\exp(ATT) - 1)}{\overline{DF\_RD}}, \qquad (12)$$

where DF_i denotes the amount of direct funding obtained by firm i and $\overline{DF\_RD} = \frac{1}{N}\sum_{i=1}^{N}\frac{DF_i}{RD_i}$ is the average share of direct support in total R&D expenditure.

Difference-in-differences estimation based on policy changes

In the estimation exploiting changes in R&D tax incentive policies, implied user cost elasticities are calculated as:

$$e^{TaxChange} := \frac{ATT}{\Delta \log \overline{BIndex}^{treated} - \Delta \log \overline{BIndex}^{control}}, \qquad (13)$$

where $\Delta \log \overline{BIndex}^{treated}$ and $\Delta \log \overline{BIndex}^{control}$ respectively mark the log change in the average B-index of treated and control firms between the last pre-reform year and first post-reform year in the estimation sample.[59] As data on the actual amount of R&D tax support received by firms are currently not available for several participating countries, incrementality ratios are derived from the implied user cost elasticities $e^{TaxChange}$, in line with the analytical derivation and assumptions adopted in the micro-aggregated analysis (**Section 3.1.2**).

$$IR^{TaxChange} := \frac{dRD}{dTS} \frac{1}{1-\tau} * \frac{e^{TaxChange}}{e^{TaxChange}(1-\overline{BIndex})-\overline{BIndex}}, \qquad (14)$$

where d denotes a marginal change. The formula is again evaluated for an average firm, and the corporate incomes tax rates τ and B-Index are calculated as averages of these variables between the last pre-reform year and first post-reform year in the sample.[60]

4.2. Results for R&D tax incentives

4.2.1. Difference-in-Differences estimation based on policy uptake

The estimates based on R&D tax support uptake indicate that R&D tax incentives increase firm's total R&D expenditure (sum of intramural and extramural R&D) in all countries considered, with implied user cost elasticities ranging from -0.17 to -3.07 (**Table 23**).

The estimated average treatment effect on the treated (ATT) is positive and statistically significant in all cases. Estimates of treatment effects cannot be compared across countries, as the treatment "dose" varies, i.e. tax incentives are more generous in some countries than others. However, the user cost elasticities implied by the treatment effects can, in principle, be compared if taking into account a full range of contextual factors. These elasticities vary significantly: they are (in absolute value) greater than 2 in the case of Belgium, Norway, Portugal and Sweden and rather low (-0.17) in the case of France, with Australia and the Czech Republic in between.

The incrementality ratios implied by the estimates are of potential interest to policy makers (bottom line of **Table 23)**. They are close to or greater than 1 for most countries, indicating neutral and in some cases crowding-in effects. According to this, there are instances where firms increase their R&D by an amount over and above the amount of tax support they receive. The incrementality ratios for Belgium, Norway, Portugal and Sweden are particularly large, but broadly in line with recent firm-level estimates for the payroll exemption in Belgium (Dumont, 2017), Canada (Agrawal et al., 2020), Norway (Benediktow et al., 2018), the United Kingdom (Dechezleprêtre et al., 2016) and the United States (Rao, 2016).[61] The estimate of 1.4 for Australia is also similar to the one obtained in the recent evaluation by Thomson, Skali and Holt (2016).[62] The implied incrementality ratio for the Czech Republic is 1.01.

Table 23. Diff-in-diff estimates of the impact of R&D tax support

R&D tax relief beneficiaries vs. non-beneficiaries

Country	AUS	BEL	CZE	FRA		NOR	PRT	SWE
Dependent variable: log R&D expenditure (Intra+Ext)	(1)	(2)	(4)	(5a)	(5b)	(6)	(7)	(8)
Effect of tax incentives (*ATT,*	0.135**	0.351***	0.161***	0.080***	0.234***	0.302***	0.742***	0.142**
not comparable across countries)	(0.059)	(0.09)	(0.046)	(0.024)	(0.088)	(0.062)	(0.113)	(0.065)
Observations	7678	1504	6017	6673	865	2474	2014	1633
Implied user cost elasticity	-0.90	-2.07	-0.63	-0.17	-0.49	-2.42	-1.14	-3.07
Implied incrementality ratio	**1.41**	**3.50**	**1.01**	**0.34**	**1.09**	**1.90**	**3.23**	**2.62**

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for log firm sales (employment if sales not available), firm fixed effects and year fixed effects. Matched sample constructed using coarsened exact matching by year, size class, macro industry, R&D quintile and direct support receipt status. In column 5a, the estimation is carried out based on the full sample of French firms, while in column 5b, the estimation sample is restricted to French firms in the lower half of the R&D distribution.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

France stands out as having the lowest estimated incrementality ratio (0.34) implied by the estimates (column 5a), but this is at least partly due to the relatively large level of R&D expenditure of an average firm in the estimation sample for France.[63] Firms in the matched estimation sample for France are much larger than firms in the samples for the other countries: a median treatment or control firm in France has about 300 employees and intramural R&D expenditure of USD 1.8 million, compared to 40-100 employees and R&D expenditure of about USD 150-600 thousand in most other countries. Most of the firms entering the estimation are in the upper half of French R&D performers in terms of their (initial) intramural R&D expenditure. Restricting the estimation sample to firms in the lower half of the R&D distribution (column 5b) gives a much larger effect of tax incentives: it implies a user cost elasticity of 0.49 and an incrementality ratio around 1, which is more in line with the results found for other countries, although still on the lower end.

Incrementality ratios estimated at the firm level (about 2 on average across the 7 countries considered in **Table 23**) tend to be somewhat higher than those obtained from the micro-aggregated analysis in **Section Chapter 3.** . This can be explained by the notion that R&D is a highly concentrated activity – most firms perform comparatively little R&D, and R&D expenditure at the country-industry-size class level is largely determined by the expenditure of a limited number of large R&D performers, whom **Section Chapter 3.** established to be less responsive to R&D tax incentives. As a consequence, the micro-aggregated estimates are prone to be lower than firm-level estimates which give equal weight to each firm.

When comparing the firm-level results across countries or estimation approaches (based on policy uptake vs. policy change), it is also important to bear in mind that each estimate captures an average effect *for the treated firms*, i.e. for the firms that are observed to start receiving tax or direct support or that are affected by a policy change. To the extent that the uptake of public support differs across firms with different characteristics – as suggested by the micro-aggregated analysis – differences in the composition of the treated group will translate into differences in the estimated effects. For example, a policy change that affects large firms can be expected to have different effects from a policy change that affects SMEs, even if the effect of R&D tax incentives is the same for a given type of firm in both countries. For this reason, it is imperative to take into account the differences in the characteristics of treated firms when interpreting the effects of policy changes.

However, at least part of the variation in the results across countries reflects real differences in the effectiveness of different schemes, rather than just different sample composition. As more firm-level estimates become available through the microBeRD project, future work could employ meta-analysis methodologies to link the estimated differences in policy effectiveness to various features of policy design.

4.2.2. Difference-in-Differences estimation based on policy changes

The difference-in-differences analysis based on concrete policy changes provides a way to estimate the effects of tax incentives for countries without access to administrative R&D tax relief data. This also provides a way to test the robustness of the findings based on R&D tax incentive use, exploiting a different source of variation.

Note that the estimates using this approach can be interpreted as the average treatment effect on the treated firms (ATT), which can in general differ from the overall average treatment effect (ATE). For example, if SMEs react to R&D tax incentives more strongly than large firms, then ATT should be higher than ATE in the case of the policy change in Australia (SMEs from the treated group). Similarly, ATT should be smaller than ATE in the case of the policy change examined in Japan which affected large firms.

The treatment effects estimated based on policy changes (**Table 24**) confirm the generally positive effects of R&D tax incentives on firms' total intramural and extramural R&D expenditure[64], although the baseline estimates are not statistically significant in the case of Australia, Austria, Chile[65] and Sweden (ceiling-based estimate).[66] The estimates for Australia, Austria and Sweden actually become statistically significant if firms far away from the firm size threshold or R&D ceiling are kept in the sample (see **Section 4.1.1**).

Overall, the incrementality ratios based on the analysis of policy changes are broadly in line with those reported above based on business experience of R&D tax support. As found previously, the incrementality ratios are fairly high for Belgium, Norway and Sweden. The estimated input additionality for France is somewhat higher than found previously for the full sample, although lower than what was found previously for the bottom half of the R&D distribution.

Table 24. Diff-in-diff estimates of the impact of R&D tax incentives based on policy changes

Country	**AUS**	**AUT**	**BEL**	**CHL**	**FRA**	**ITA**
Treatment group	SME	Above ceiling	Recipients	Recipients	Recipients	Recipients
Dependent variable: log R&D	**Int.+Ext.**	**Ext.**	**Intramural+Extramural**			
	(1)	(2)	(3)	(4)	(5)	(6)
Effect of tax incentives (*ATT*,	0.05	-0.172	0.171**	0.103	0.165***	-0.077***
not comparable across countries)	(0.078)	(0.124)	(0.072)	(0.136)	(0.032)	(0.030)
Observations	4695	1167	1528	2056	23544	18860
Implied user cost elasticity	-0.69	-2.41	-1.55	-0.33	-0.41	-0.49
Implied incrementality ratio	1.03	2.99	**2.30**	0.45	**0.77**	**0.78**
Country	**JPN**	**NOR**	**NOR**	**SWE**	**SWE**	
Treatment group	Large	Below ceiling	Recipients	Below ceiling	Recipients	
Dependent variable: log R&D	**Intramural+Extramural**					
	(7)	(8)	(9)	(10)	(11)	
Average Treatment Effect (*ATT*,	0.052**	0.402***	0.193***	0.053	0.118*	
not comparable across countries)	(0.021)	(0.065)	(0.056)	(0.073)	(0.061)	
Observations	11024	2837	4045	1582	2563	
Implied user cost elasticity	-0.48	-2.14	-1.20	-0.83	-2.13	
Implied incrementality ratio	**0.85**	**2.67**	**1.64**	1.07	**2.66**	

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for log firm sales (employment if sales not available), firm fixed effects and year fixed effects.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

The policy changes diff-in-diffs estimation approach allows to extend the analysis to Austria, Italy and Japan. The estimates for Austria imply a rather high incrementality ratio that is, however, imprecisely estimated. For Italy and Japan, the implied input additionality is slightly below 1. In the case of the Italian tax credit, available from years 2007-2009, both the measured and the actual additionality were likely reduced by changes in the tax relief payment policy that were made in 2008 and 2009 and implied that some firms that submitted requests to receive tax relief for R&D performed in 2008 and 2009 only received this support in 2010 or 2011.[67] In the case of Japan, the comparatively lower additionality is likely due to the fact that the treatment group consists of large firms with capital above the SME thresholds. The median treated firm in the estimation for Japan has almost 500 employees and performs over USD 2 million of R&D, which is substantially more than in other countries.

The firm-level effects of tax incentives on other R&D related outcomes are documented in **Table D.1**.[68] These estimates indicate a variation in the structure and orientation of the induced R&D across countries, and, with the exception of Belgium, there is little evidence of an effect on R&D wages, in line with the micro-aggregated analysis.[69] R&D labour expenditure increases in most countries, but other current R&D expenditure also plays an important role in Australia, the Czech Republic, France and Portugal, and R&D capital in Japan. In terms of orientation of R&D, the results indicate that R&D tax incentives induce mainly experimental development in Australia, Belgium and France, mainly basic and applied research in Chile and both types of R&D in Norway and Portugal. Estimates for the Czech Republic and Sweden are also consistent with similar effects for both types of R&D but are mostly not statistically significant.

4.3. Results for direct government funding of business R&D

4.3.1. Difference-in-Differences estimation based on policy uptake

An advantage of the estimation based on the data on support beneficiary status is that it also allows estimating the effect of direct support following the same approach that was used to estimate the effect of R&D tax incentives.

The firm-level analysis of the impact of direct government funding (**Table 25**) finds evidence of a positive effect on firms' total intramural and extramural R&D expenditure. The estimated effects of receiving any direct support for R&D are positive and statistically significant in all countries. The incrementality ratios implied by the estimates indicate crowding out of privately funded R&D by public funds for four countries (Germany, France, Italy and Portugal) and crowding in for six countries (Austria, Canada, the Czech Republic, Japan, New Zealand and Norway).[70] As above, the point estimates cannot be directly compared across countries, and incrementality ratios should be used instead for making comparisons. The gross incrementality ratios derived based on the treatment effects range from 0.28 to 2.89. On average, the gross incrementality ratios for direct funding appear slightly lower than those for tax incentives reported above. Across countries, the average incrementality ratio of direct funding is 1.4 – slightly below the incrementality ratio for R&D tax incentives following the same methodology (2.0) and consistent with the incrementality ratio of direct funding obtained from the micro-aggregated analysis (1.5).

Table 25. Diff-in-diff estimates of the impact of R&D direct government funding

Direct support recipients vs. non-recipients

Dependent variable:	AUT	CAN	CZE	DEU	FRA
log R&D expenditure (Intra+Ext)	(1)	(2)	(3)	(4)	(5)
Average Treatment Effect (*ATT,*	0.352***	0.304***	0.428***	0.105***	0.115***
not comparable across countries)	(0.047)	(0.034)	(0.059)	(0.018)	(0.028)
Observations	8146	113650	8134	43256	26025
Implied incrementality ratio	**2.26**	**1.58**	**1.31**	**0.56**	**0.60**
Dependent variable:	**ITA**	**JPN**	**NOR**	**NZL**	**PRT**
log R&D expenditure (Intra+Ext)	(6)	(7)	(8)	(9)	(10)
Average Treatment Effect (*ATT,*	0.179***	0.127***	0.459***	0.514***	0.209**
not comparable across countries)	(0.051)	(0.017)	(0.077)	(0.124)	(0.098)
Observations	27049	172444	4211	789	3714
Implied incrementality ratio	**0.48**	**1.38**	**2.89**	**2.83**	**0.70**

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the firm level. All regressions control for log firm sales (employment if sales not available), firm fixed effects and year fixed effects. Matched sample constructed using coarsened exact matching by year, size class, macro industry and R&D quintile.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

The firm-level effects of direct funding on other R&D related outcomes are documented in **Table D.2**. The effects on other current expenditure tend to be stronger compared to those on R&D labour costs. The effects on R&D capital are comparatively strong for some countries (e.g. the Czech Republic, France, Japan) but essentially zero for some others (New Zealand, Portugal). The increased labour R&D expenditure translates into higher R&D employment, while no evidence of an increase in R&D unit labour costs is found. Finally, in most countries the effect of direct funding seems similar or stronger for basic and applied research, although it is stronger for experimental development in the case of Austria and Norway.

Chapter 5. Conclusions and next steps

The microdata-based impact analysis carried out in the first phase of the microBeRD project (2016-19) has investigated the effectiveness of R&D tax incentives and direct government support in encouraging additional R&D investment by businesses. MicroBeRD adopts a distributed approach that combines the advantages of cross-country studies based on country or industry-level data with the strengths of country-specific studies undertaken at the firm level. Two types of microdata-based impact analyses have been carried out: a cross-country analysis based on pooled, micro-aggregated data in 20 countries, and distributed regressions at the firm level within 14 countries.

The results based on R&D survey data indicate a gross incrementality ratio ("bang for the buck") for R&D tax incentives of around 1, implying that, on average, one extra monetary unit of R&D tax support translates into one extra unit of R&D. Accounting for the fact that not all eligible firms actually benefit from tax incentives may increase the implied incrementality ratio of tax support by about a third to 1.4.

The results presented in this paper highlight the importance of applying a micro-based approach to policy impact analysis across countries. The report presents evidence of multiple mechanisms of impact for R&D tax incentives as well as several instances of heterogeneity in the business response to tax support measures. R&D tax incentives have impacts within and across firms, both inducing companies to engage in R&D for the first time and modifying levels of R&D for companies that already perform R&D within them. Firms performing less R&D are found to be more responsive to R&D tax incentives. Small firms are also more responsive than medium-sized and especially large companies, but this is due to the fact that they, on average, perform less R&D rather than due to their employment size *per se*. The larger effect of R&D tax incentives on firms that perform comparatively little R&D implies that R&D tax incentive schemes that cap the amount of supported R&D expenditure or reduce the rate of R&D tax credit/allowance once a certain threshold has been reached are likely to show greater input additionality.[71]

This analysis has also provided a basis for reconciling impact estimates derived from different methodologies and data sources. Since R&D is, by and large, a highly concentrated economic activity, aggregate estimates will tend to reflect more closely the experience of large R&D performers, while firm-level analysis will highlight impacts on an "average" R&D performer, which tends to do comparatively little R&D. Meso-level estimates, as those based on the pooled analysis of micro-aggregated data by groups of business characteristics, provide insights on the links between the other two.

Although the report's primary focus is on R&D tax incentives, it also provides evidence on the input additionality of direct government funding of business R&D and general reductions in the corporate income tax rates. Both the micro-aggregated and the firm-level analysis suggests that one monetary unit of direct support induces approximately 1.4 units of additional R&D. This corresponds to a slightly higher input additionality than that found for tax incentives, but input additionality estimates for both instruments converge when taking into account that not all eligible firms actually receive tax relief. Lower corporate income tax rates also seem to encourage R&D investment, but with a substantially lower incrementality ratio of 0.24. However, comparing the impact of different policy support instruments is not straightforward due to differences in the types of selection effects at play and the data and identification approaches available in each circumstances.

Ultimately, explicit policy objectives should determine the optimal support policy-mix choices. The evidence in this report is relevant to such decisions. For example, the results indicate that the effect of tax incentives is largely concentrated on inducing experimental development in firms, as opposed to research (basic or applied). Direct government funding of R&D appears in contrast more conducive to raising research as opposed to experimental development. It is well known that direct support confers a larger degree of discretion on the part of policy makers or agencies delegated to administer support. Incrementality ratios, measuring the amount of R&D induced by one dollar of public funding, represent an important input into cost-benefit analysis, but alone they are not sufficient to make claims on whether benefits of a policy outweigh its costs. Such claims would require additional calculations involving assumptions about the private and public returns to the R&D induced by the evaluated instrument and also about the opportunity costs of the public funds used to finance it.[72]

The results suggest that R&D tax incentives are a more suitable tool for encouraging the formalisation and extension of product and process development activities in the business sector without interfering in the choice of product or process being developed.[73] In contrast, direct government funding is comparatively more effective at promoting research that while still oriented towards an application it is away from being ready to be implemented in the market. It would be desirable in the future to count with a richer characterisation of government funding of business R&D in order to differentiate among a wide range of possible direct support instruments and requirements. The analysis also hints at a potential complementarity between R&D tax incentives and direct support, as one tool is found to be more effective in the presence of the other.

The OECD microBeRD project has thus far focused on analysing the impact of R&D support policies on innovation *inputs*, as input additionality is a necessary (yet not sufficient) condition for output additionality and this type of analysis exhibits lighter data requirements. R&D surveys, alone or in combination with tax relief data, are sufficient for the basic analysis of input additionality. Analysis of impacts on innovation outputs or economic outcomes would require matching R&D surveys to additional datasets, such as innovation surveys, patent data or production surveys.

The planned continuation of the microBeRD project seeks to deepen and extend the current analysis on input additionality. Thus, microBeRD+ will focus on extending data linking efforts within countries to explore the effect of R&D support policies on innovation outputs (e.g. introducing new products and services, filing patents) and economic outcomes (e.g. employment and productivity growth). In addition to this, the results in this paper point to a number of possible refinements of the current analysis, by dwelling further on the complex relationship between tax incentive design[74], additionality and the innovation support policy mix over time. This will require the continued engagement with national experts on R&D statistics and collaboration across different branches of government with relevant data and policy responsibilities. The activities conducted under microBeRD have already proved effective at facilitating such dialogue and demonstrating the value to individual countries of having in place inter-connected data infrastructures on innovation policies. As the number of participants in this project progressively increases over time, the microBeRD approach continues to demonstrate the possibility to use microdata effectively and securely to inform public policy within and across countries.

Endnotes

[1] A recent study for the United States (Lucking, Bloom, and Van Reenen, 2018) finds private returns of about 15% but social returns of around 60%. See Bloom, Van Reenen and Williams (2019) for a review of studies estimating spillovers from business R&D.

[2] Other instruments may focus on the outputs of R&D activity, for example enhancing the potential upside of R&D by reducing the tax due arising from the outputs of R&D.

[3] Becker (2015) and Bloom, Van Reenen and Williams (2019) take a broad look at the various policies for boosting business innovation. Hall (2019) provides a comprehensive survey of the literature on tax policy for innovation, including income-based R&D tax incentives ("patent boxes"). Gaessler, Hall and Harhoff (2018) offer a discussion of income-based R&D tax incentives, arguing that invention itself is not affected by these incentives. Innovation can also be influenced by other indirect support mechanisms, such as general government procurement of new goods and services that prompt firms to invest in R&D and other innovation activities to ensure their development (Appelt and Galindo-Rueda, 2016).

[4] To ensure cross-country comparability, the analysis focuses on small, medium-sized and large firms. Many countries do not cover micro firms with less than 10 employees in business R&D surveys.

[5] See http://www.oecd.org/sti/inno/oecdinnovationmicrodataproject.htm, http://www.oecd.org/sti/ind/multiprod.htm and http://www.oecd.org/sti/dynemp.htm.

[6] Most of the data available for this study are based on guidance within the 2002 edition of the OECD Frascati Manual. Data fully consistent with the most recent 2015 update are now becoming available.

[7] Different enterprise concepts – variably defined enterprise units, plants and establishments or enterprise groups – exist and may be adopted by countries in business R&D surveys and the computation of R&D tax benefits at firm level. This has implications for the comparability of indicators collected in regular data collections as well as those compiled by microBeRD (e.g. concentration statistics). While warnings flags are provided in this report, whenever country-specific enterprise definitions were reported, further OECD work aims to investigate this issue in more detail. This includes the collection of additional metadata and review of the existing firm size definitions, including guidance on independence.

[8] For information on the eligibility of current and capital expenditure for R&D tax relief in OECD countries and partner economies, see http://www.oecd.org/sti/rd-tax-stats-expenditure.pdf.

[9] This assumption is necessary because the microBeRD project has not yet exploited micro-level profit/tax liability information as such information is challenging to obtain and link to R&D microdata in most countries. The inclusion of profit/tax liability information is an important avenue for future work, subject to the availability of relevant microdata.

[10] See Thomson (2017) for a cross-country analysis exploiting industry-level (but not size class-level) variation.

[11] Because of the log specification, the estimated parameters (elasticities) reflect percentage changes in R&D expenditure or other R&D outcomes to percentage changes in the user cost of R&D.

[12] To allow for an interpretation of the estimated coefficients as price elasticity of R&D, both the R&D and B-index variables enter the regression in logarithms, leading to a "log-log" specification.

[13] See Goolsbee (1998) and Lokshin and Mohnen (2013).

[14] In calculating the interaction term, direct support is normalised by the level of intramural R&D expenditure by firms in a given country-industry-size class group. This ensures that the interaction term captures the intensity of direct support and not just the number of firms in that country-industry-size class cell.

[15] R&D microdata for several countries are available only biannually, so two-year, rather than one-year, lags are employed throughout the report.

[16] Please note that despite the use of an outcome variable that does not include direct funding as a component, the direct funding variable could still be endogenous if country-size-industry groups that become more (less) active in the area of R&D also apply for and obtain more (fewer) R&D grants. For this reason, the results for direct support should be treated as exploratory and interpreted with caution.

[17] Tax subsidies feature at least partially in firm's own financing of BERD (Appelt et al., 2019).
[18] The small differences in the number of observations by size class are due to data cells that did not pass national confidential requirements.
[19] See Hall and Van Reen (2000), Mohnen and Lokshin (2009), What Works Centre for Local Economic Growth (2015) and Appelt et al. (2016) for surveys.
[20] See Poot, Hertog and Brouwer (2003), Dechezleprêtre et al. (2016), Guceri and Liu (2017) and Dumont (2017).
[21] See, for instance, Bloom, Griffith and Van Reenen (2002), Guellec and Van Pottelsberghe De La Potterie (2003) and Thomson (2017).
[22] The analytical derivation is based on the total derivative of $GTARD$ and exploits the relationship between BERD and the B-Index established through the regression estimation ($dlog\ BERD = \beta_g^{TAX}\ dlogBIndex$).
[23] The estimation of the B-Index at the firm-level accounts for thresholds and ceilings on R&D expenditure (see Section 2.2.2).
[24] Forgone CIT revenues resulting from a one percentage point reduction of CIT rates are obtained by dividing corporate income tax revenues (total government level) by the combined (central and sub-central) non-targeted CIT rates. Corporate income tax revenues and corporate income tax rates are sourced from the OECD Revenue Statistics and OECD Corporate Tax Statistics databases.
[25] Micro-aggregated statistics on the level of BERD net of direct funding are currently not part of microBeRD output but may be added in the future. BERD net of direct government funding would include funds received by foreign parents and other domestic firms that may have some affiliation links and indirectly benefit from support.
[26] Thomson's (2017) estimates imply a long-term elasticity around 4, but the author himself warns against putting too much weight on the implied long-term elasticity given its sensitivity to the estimated autoregressive coefficient.
[27] This increase is mainly due the use of BIndexTax rather than the change in sample composition
[28] Labeaga Azcona et al. (2014) discuss the distinction between ex-ante claimable and ex-post claimed tax relief and its impact on the estimated effects of R&D tax incentives.
[29] R&D may increase as a result of firms formalising some of their pre-existing innovation activities if those had previously met the other criteria laid out in the OECD Frascati Manual (OECD, 2015). One possible channel of impact of R&D tax incentives is the inducement to firms to formalise their innovation activities. This should however be a substantive process and imply much more than a simple relabelling of existing activities.
[30] This also extends to investigating the similarities and differences between R&D support claims and R&D statistics, as businesses are likely to draw on common internal records to report on both instances.
[31] Akcigit and Stantcheva (2020) provide a comprehensive review of the different channels through which tax policies can affect innovation, examining the following five margins: i) the quantity and quality of innovation; ii) the geographic mobility of innovation and inventors across U.S. states and countries; iii) the declining business dynamism in the U.S., firm entry, and productivity; iv) the quality composition of firms, inventors, and teams; and v) the direction of research e ort, e.g., toward applied versus basic research, or toward dirty versus clean technologies.
[32] Basic and applied research are combined in the analysis because basic research accounts for a small share of intramural R&D – 10% for an average cell in the estimation database.
[33] See, for example, Goolsbee (1998), Haegeland and Møen (2007) and Lokshin and Mohnen (2013).
[34] Full-time equivalent (FTE) of R&D personnel is defined as the ratio of working hours actually spent on R&D during a specific reference period (usually a calendar year) divided by the total number of hours conventionally worked in the same period by an individual or by a group.
[35] The effect on the number of researchers is very similar to that on the total R&D employment (which also includes R&D technicians and other R&D non-researcher staff).
[36] A potential caveat, particularly relevant for the analysis of the impacts at the extensive margin, is that the presence of tax incentives could increase the *measured* number of R&D performers even if the actual number does not change. This would be the case if administrative tax relief data helped national statistical offices better identify R&D performing firms within the sampling framework of business R&D surveys. One possible way to address this concern would be to study the extensive margin using innovation survey data, which cover both firms that perform R&D and those that do not. Subject to the availability and potential

of linking relevant micro data in participating countries, this option will be explored in more detail in the second phase of the microBeRD project.

37 Larger effects of tax incentives on smaller firms are found by Haegeland and Møen (2007), Baghana and Mohnen (2009), Lokshin and Mohnen (2012), Azcona et al. (2014) and Kasahara, Shimotsu and Suzuki (2014). A meta-analysis by Castellacci and Lie (2015) also indicates stronger effects of tax incentives for SMEs. In contrast, Rao (2015) does not find systematic differences in user cost elasticities across firm size quintiles.

38 High R&D intensive industries include Pharmaceuticals, Computer manufacturing, Scientific R&D. Medium R&D intensive industries include Chemicals, Electrical equipment, Machinery and equipment, Transport equipment and IT services.

39 Highly digital-intensive industries include Computer manufacturing, Machinery and equipment, Transport equipment, Telecommunications, IT services, Finance, Legal and accounting, Scientific R&D, Advertising, Administrative services and Activities of membership organisations.

40 For more details see, https://ec.europa.eu/eurostat/cache/metadata/en/htec_esms.htm.

41 The estimates considered in the calculation of incrementality ratios are based on the synthetic B-Index ($BIndex_t^{syn2}$) and intramural R&D as outcome variable (see column 5 in **Table 4**).

42 In other words, the interval 0.83-1.15 covers the "true" incrementality ratio with a probability 90%.

43 The semi-elasiticities estimated here for business R&D investments are of a similar degree of magnitude as those estimated for patenting (see, e.g., Griffith et al., 2014; Akcigit et al. 2018; Alstaedter et al., 2018; Cai et al. 2018; and Akcigit and Stantcheva, 2020).

44 Both intramural and extramural R&D expenditure can be affected by tax incentives, so it is desirable to analyse the impact of the tax incentives on both types of R&D expenditure. In the micro-aggregated estimation, adding up intramural and extramural expenditure might result in double-counting – intramural R&D of some firms can be funded by extramural R&D expenditure of other firms – so only intramural R&D was used as outcome in the baseline specification. In a firm-level analysis, however, the double-counting is not an issue, so both intramural and extramural R&D expenditure are included in the outcome variable.

45 If R&D tax subsidy rates based on the B-Index were used as explanatory variable in the firm-level analysis, a similar problem would arise. For instance, in Australia and in Japan, SMEs are eligible for higher tax credit rates than large firms. As large firms on average perform more R&D than SMEs, this generates a negative correlation across firms between the tax subsidy rates they face and their R&D performance, even if R&D tax incentives actually increase R&D performance.

46 For simplicity, the terms "direct support" and "R&D grants" are used interchangeably. It is, however, important to keep on mind that direct funding also includes government R&D contracts.

47 Using T to denote the year of first receiving tax relief, firms are required to be observed in the data in years T-2, T-1, T, T+1 and T+2. This requirement is conditional on the R&D microdata being available for given years. For example, in a case where firms starting to use tax relief in year T and the microdata end in year T+2, the firms are kept in the treated set as long as they appear in the data in years T-2 to T+1. The same applies in the case of countries where the R&D microdata is collected only every other year.

48 See Blackwell et al. (2009) and Iacus et al. (2011, 2012).

49 The estimation is performed in Stata by first using the *cem* command to produce matching weights and then estimating weighted regressions with the *xtreg* command.

50 Note that the treatment and reform dummies enter the equation only in an interaction and not separately, as the firm and time fixed effects absorb the non-interacted dummy variables.

51 Firm-level estimation has not been undertaken for Spain and Switzerland because the R&D microdata available for analysis for Spain consisted of repeated cross-sections rather than a panel, and the microdata for Switzerland include only 4 waves spread over a 10-year period owing to the frequency with which business R&D surveys are undertaken in the country.

52 Additionally, estimates based on tax incentive uptake have also been produced for Canada and Chile, and estimates based on receiving direct support for Australia, Chile and Sweden. These estimates are not reported because the number of treated and/or control firms was less than 50 in these cases, so the estimates have not been considered sufficiently robust.

53 Large firms have become eligible for SkateFUNN only in 2003. We ignore this in the illustrative example shown here but reflect it in the estimation.

54 See Haegeland and Møen (2007) and Bøler, Moxnes and Ulltveit-Moe (2015) for examples of a similar methodology.

[55] Note that the treatment and change dummies enter the equation only in an interaction and not separately. This is because the firm and time fixed effects absorb the non-interacted dummy variables.
[56] This approach is related to the firm-level difference-in-differences matching analysis based on policy uptake discussed earlier. However, while that analysis observes multiple cohorts of firms starting to use the tax incentives in different years, the estimation discussed here focuses on the initial cohort of R&D tax relief beneficiaries that started to receive R&D tax support following the introduction or major reform of existing R&D tax incentives. For this cohort, the timing of starting to use the tax incentives is largely determined by the policy change and, as such, is less likely to be correlated with some firm-specific time-varying factors that could also be driving R&D performance. Also, the approach discussed here does not make use of matching.
[57] Belgium introduced an R&D tax credit in 2007. The results reported for Belgium (sample period 2001-2007) reflect primarily the effect of the partial exemption rather than tax credit which only had limited uptake in the first years.
[58] The R&D tax credit was extended from 2009 to 2011 but was only available to firms that had incurred qualifying R&D expenditure in 2007-09 and not yet received tax relief. (see http://www.oecd.org/sti/rd-tax-stats-italy.pdf).
[59] For Norway, 2003 is used as the first post-reform year because large firms become treated only in 2003.
[60] Using an alternative formula, similar to the approach taken by Dechezleprêtre et al. (2016), gives very similar incrementality ratios.
[61] Following a similar estimation approach as the one taken here, Benediktow et al. (2018) arrive at an incrementality ratio of 2.04 (for an average generation of tax credit recipients and firms with strictly positive past R&D. Agrawal et al. (2020 estimate user cost elasticities between 1 and 3. Dechezleprêtre et al. (2016) arrive at an implied elasticity for SMEs of 2.6, leading to incrementality ratios of 2.13 for enhanced R&D deductions and 2.8 for a refundable tax credit. Rao's (2016) instrumental variable estimates imply a user cost elasticity around 2. Dumont (2017) estimates the effect of R&D tax incentives in Belgium on a scheme-by-scheme basis. The gross incrementality ratio for the payroll exemption ranges from 2.06 to 2.89, depending on the component of the scheme (R&D collaboration with universities, higher education and accredited scientific institutions, companies with R&D employees with a Master degree or equivalent) under consideration. Once different R&D tax incentives are combined, Dumont (2017) identifies a crowding out effect.
[62] Thomson and Skali (2016) find input additionality of 0.8-1.7 in an ordinary least squares analysis and 1.9 in a difference-in-differences analysis.
[63] The results for France reported in **Table 23** are based on the period 2003-2014, i.e. cover years both before and after the 2008 reform which increased the generosity of the French R&D tax credit. In an additional analysis (not reported here) separate estimates were produced for each year. Those indicate that focusing only on the post-reform period would not significantly change the results.
[64] For Austria, results are only reported for extramural R&D, because the analysed policy change in question only affected extramural R&D. The small average amounts of extramural R&D relative to intramural R&D mean that the effect of the policy-induced changes in extramural R&D on the total R&D would be distorted by noise from random changes in the intramural expenditure.
[65] The estimate for Chile is influenced by the fact that many firms receiving R&D tax relief are characterised by an intramural R&D that exceeds the expenditure ceiling and, as a result, the marginal tax subsidy rate they face is not affected by the policy change. For firms in the lower half of the R&D distribution – which are below the expenditure ceiling – the Chilean tax credit has a positive and statistically significant effect implying a user cost elasticity of -1.35 and an incrementality ratio of 1.6.
[66] The negative sign of the estimated effects for Austria and Italy are due to the fact that the analysed policy changes in these countries led to a *reduction* in the marginal subsidy rate extramural (Austria) and intramural (Italy) R&D for treated firms.
[67] As more firms than expected applied for the R&D tax credit in 2007, the first year in which the R&D tax credit was available in Italy, companies were asked to submit a request to receive R&D tax support in 2008 and 2009. Only a subset of companies were initially selected and received R&D tax support in 2008 and 2009. In 2011, the tax credit was extended so that firms that had not yet received R&D tax relief for qualifying R&D performed in the years 2007-09 could retrospectively apply for support. Moreover, companies that had been selected to receive the R&D tax credit in 2009 were only allowed to use it in the years 2010 and 2011. Analysis by Acconcia and Cantabene (2018) implies an elasticity of about 0.8 on average. The implied elasticity is larger for firms with large cash holdings and lower for firms with low

liquidity. Cantabene and Nascia (2014) compare changes in R&D performance between 2007 and 2009 for firms that were initially selected to receive the tax credit in 2009 and those that submitted a request but were not selected at first. Their analysis implies a user-cost elasticity of 1.6.

[68] The results shown in this table are based on the tax incentive use with the exception of Japan, for which results based on the comparison of large firms and SMEs are displayed.

[69] Note, however, that firm-level analysis may fail to capture general equilibrium wage effects, as it is based on comparisons across firms and the increased demand for scientists could increase R&D wages also in firms which do not themselves benefit from tax relief. The micro-aggregated estimation provides stronger evidence against the wage effects.

[70] Using R&D expenditure net of government-funded R&D as the outcome variable allows directly testing for crowding out/in.

[71] That said, it is important to keep on mind that greater input additionality does not guarantee greater output additionality or greater spillovers (Bloom et al., 2013).

[72] Full cost-benefit evaluations of R&D tax incentive schemes are rare and strongly depend on the assumptions made. See Berger (1993); Russo (2004); Parsons and Phillips (2007); Lokshin and Mohnen (2012); Foreman-Peck (2013) and Dechezleprêtre et al. (2016).

[73] This needs to be carefully managed to ensure that supported activities truly represent the required degree of novelty and do not merely reflect a relabelling of ongoing activity.

[74] Meta-analyses can provide insights into the extent to which R&D input additionality varies with the design of R&D tax incentives. Once recent example of such an analysis includes Blandinières et al. (2020).

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Annex A. **Data**

Table A.1. Country-years included in the micro-aggregated impact analysis

Year	AUS	AUT	BEL	CAN	CHE	CHL	CZE	DEU	ESP	FRA	GBR	HUN	ISR	ITA	JPN	NLD	NOR	NZL	PRT	SWE
2000				✓			✓				✓				✓					
2001			✓	✓			✓	✓		✓	✓				✓		✓		✓	
2002		✓		✓			✓			✓	✓		✓		✓		✓			
2003			✓	✓			✓	✓		✓	✓		✓		✓		✓		✓	
2004		✓		✓			✓			✓	✓		✓		✓		✓	✓		
2005	✓			✓			✓	✓		✓	✓		✓		✓		✓		✓	
2006	✓	✓		✓			✓			✓	✓		✓		✓		✓	✓		
2007	✓	✓	✓	✓			✓	✓	✓	✓	✓		✓	✓	✓		✓		✓	
2008	✓			✓	✓		✓		✓	✓	✓			✓	✓		✓		✓	
2009	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓	✓	✓		✓		✓	
2010	✓			✓		✓	✓			✓	✓		✓	✓	✓		✓	✓	✓	
2011	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓	✓	✓	✓	✓		✓	✓
2012	✓			✓	✓	✓	✓			✓	✓			✓	✓	✓	✓	✓	✓	
2013		✓	✓	✓		✓	✓	✓		✓	✓			✓	✓	✓	✓			✓
2014	✓					✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓		
2015		✓			✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓			✓
2016	✓					✓	✓		✓		✓	✓	✓		✓			✓		
2017					✓						✓									✓

Source: OECD microBeRD project, http://oe.cd/microberd, June 2020

Table A.2. Micro-aggregated indicators

Key indicators collected as part of the distributed analysis

Type of statistics	Statistical moments: mean, percentiles (p10-25-50-90), standard deviation	Counts, shares, concentration indicators
R&D statistics		
1. R&D expenditure totals and intensity		
1.1 Level of intra/extramural R&D expenditure	x	
1.2 Intramural R&D as % of domestic sales	x	
2. Structure of R&D expenditure within firms		
2.1 % of intramural R&D, by source of funding	x	
2.2 % of intramural R&D, by type of cost	x	
2.3 % of intramural R&D, by orientation of R&D	x	
2.4 % of extramural R&D, by destination of funds	x	
2.5 % of extramural in total (intra + extramural) R&D	x	
3. R&D personnel		
3.1 Number of R&D personnel	x	
3.2 Share of R&D personnel in total employment	x	
3.3 R&D labour expenditure per R&D personnel	x	
3.4 Composition of R&D personnel (%)	x	
By type of R&D staff.		
By qualification		
By gender		
4. Distribution and concentration of R&D		
4.1 Firms share in …:	x	
4.2.Share of top 10-20-50-100 largest firms in …:		x
4.3 Share of top 1-2-5-10% largest firms in …:		x
• Intramural R&D		
• Direct funding of BERD		
• Extramural R&D		
• R&D personnel		
5. Changes in R&D performance over time		
5.1 Within-firm change in R&D expenditure and personnel	x	
5.2 Number of new (no R&D in previous year) and exiting R&D performers (no R&D in next year)		x
R&D tax incentive statistics		
6. R&D tax subsidy		
6.1 B-Index (tax component of user cost of R&D)	x	
6.2. Marginal R&D tax subsidy rate (1-B-Index)	x	
6.3 Theoretical amount of R&D tax support	x	
If BERD survey matched with tax relief microdata – level, distribution and concentration of:		
6.4 Amount of R&D tax support	x	x
6.5 Qualifying R&D expenditure	x	x

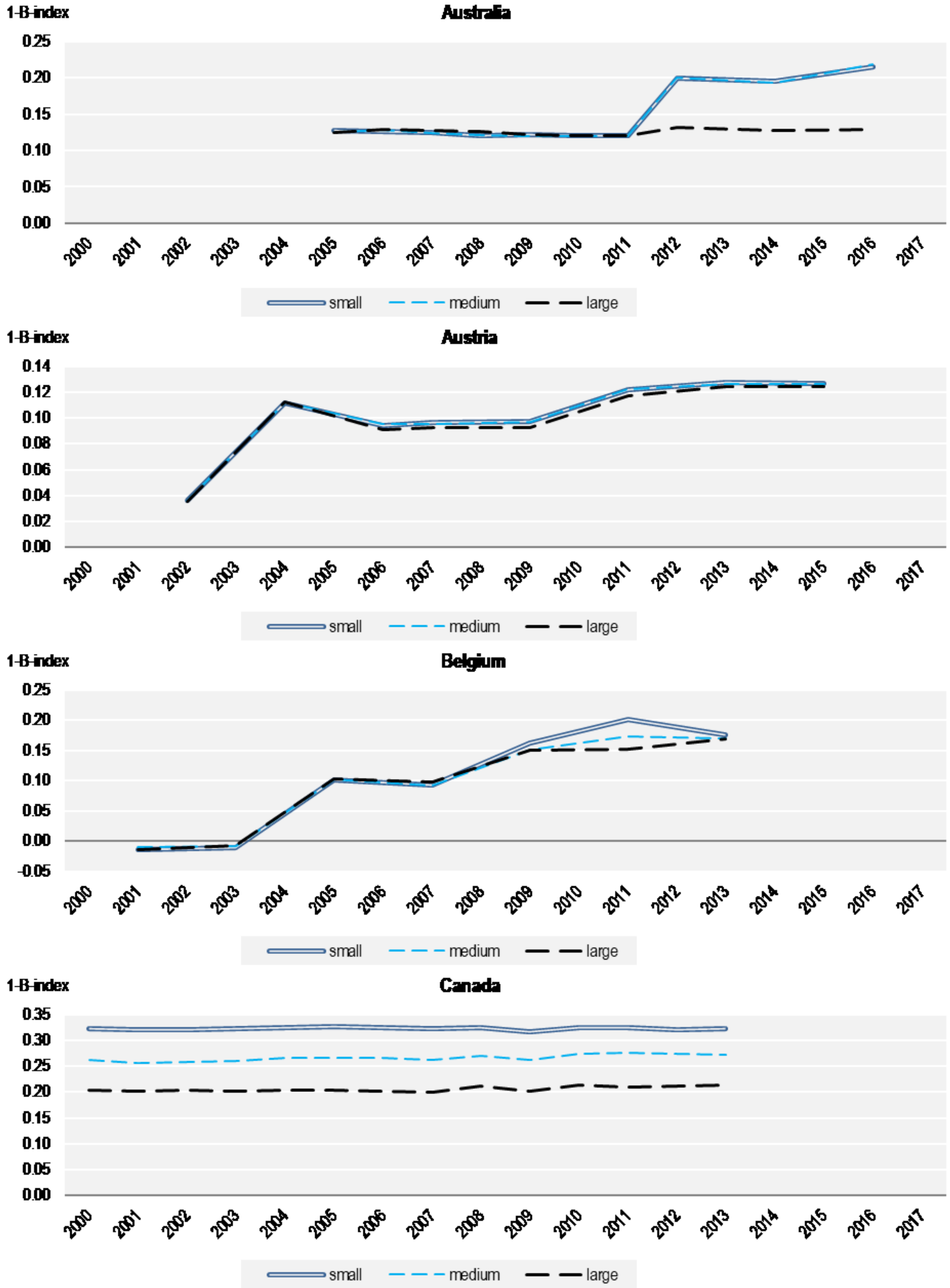
Table A.3. Main decompositions for the collection of micro-aggregated indicators

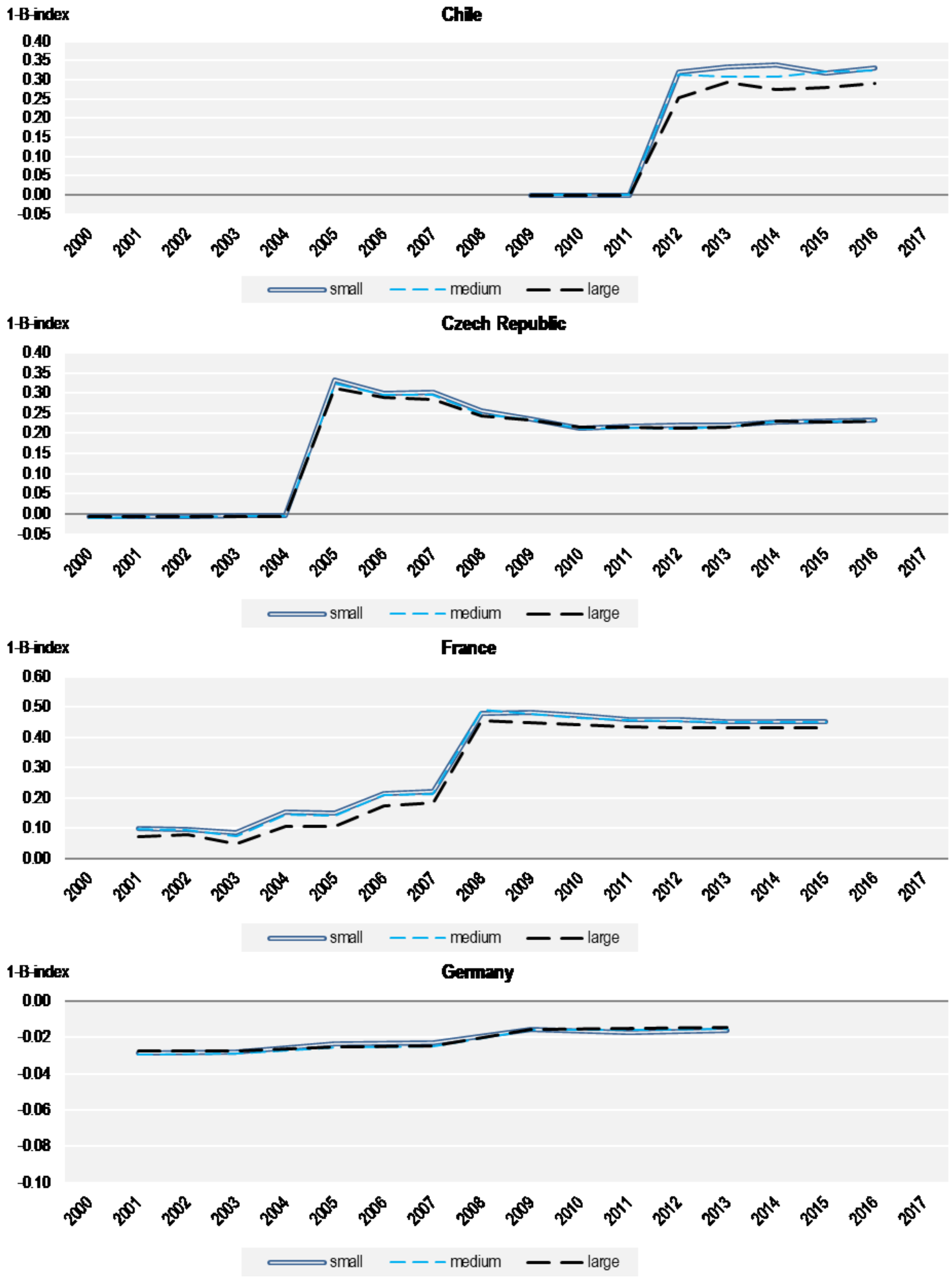
Type	Definition
All	All units
Industry (A38)	Industry according to A38 classification (38 categories).
Industry (Macro)	Macro sector (4 categories) – manufacturing, services, construction, other
Firm size	Employment size (4 categories) – thresholds 10, 50, 250 (micro, small, medium, large).
Age	Age (2 categories) – threshold 5 years (in line with OECD MultiProd project).
Cross-tabulations (interactions)	Industry (A38) x Firm size, Industry (Macro) x Firm size x Age

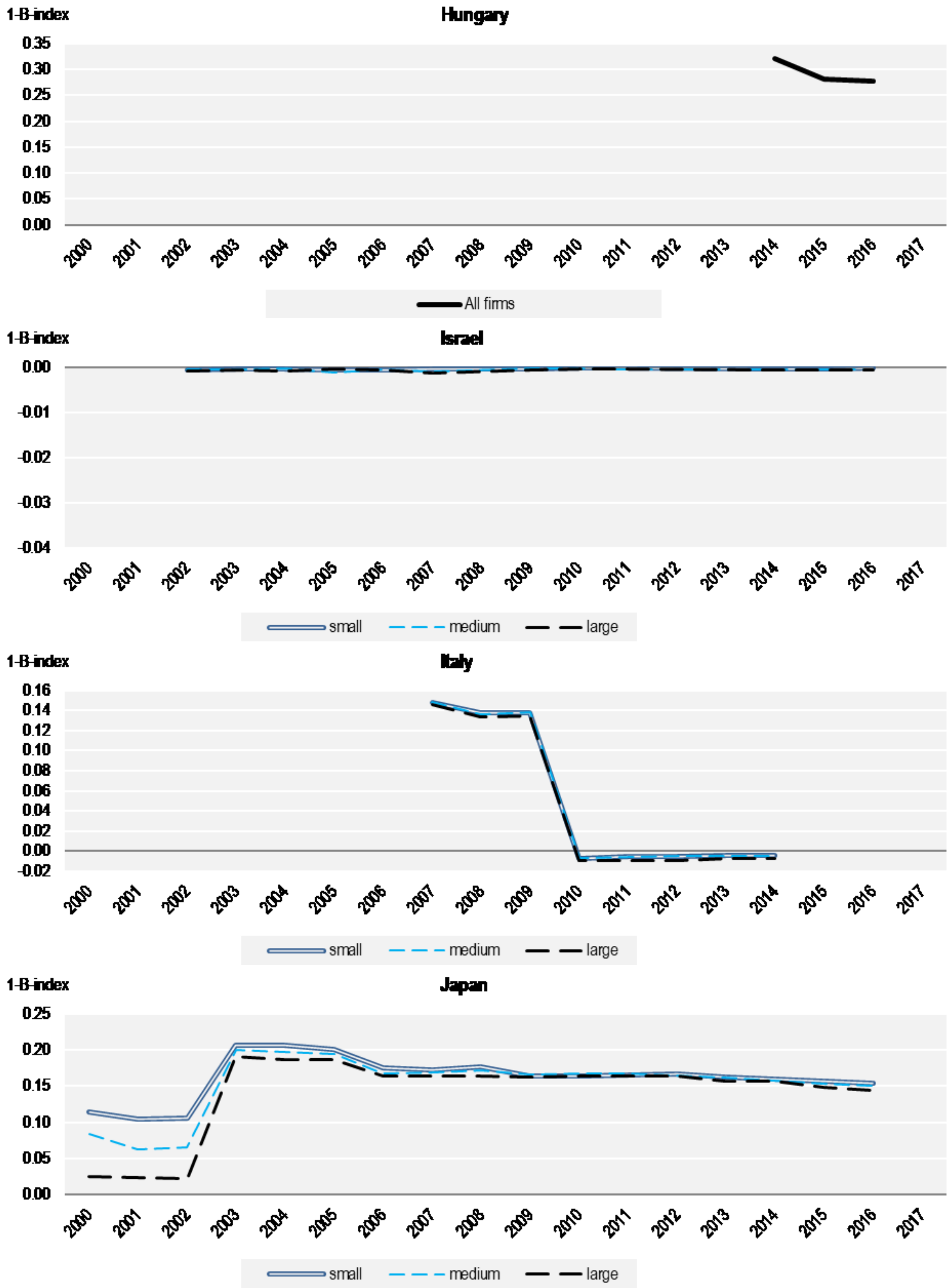
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

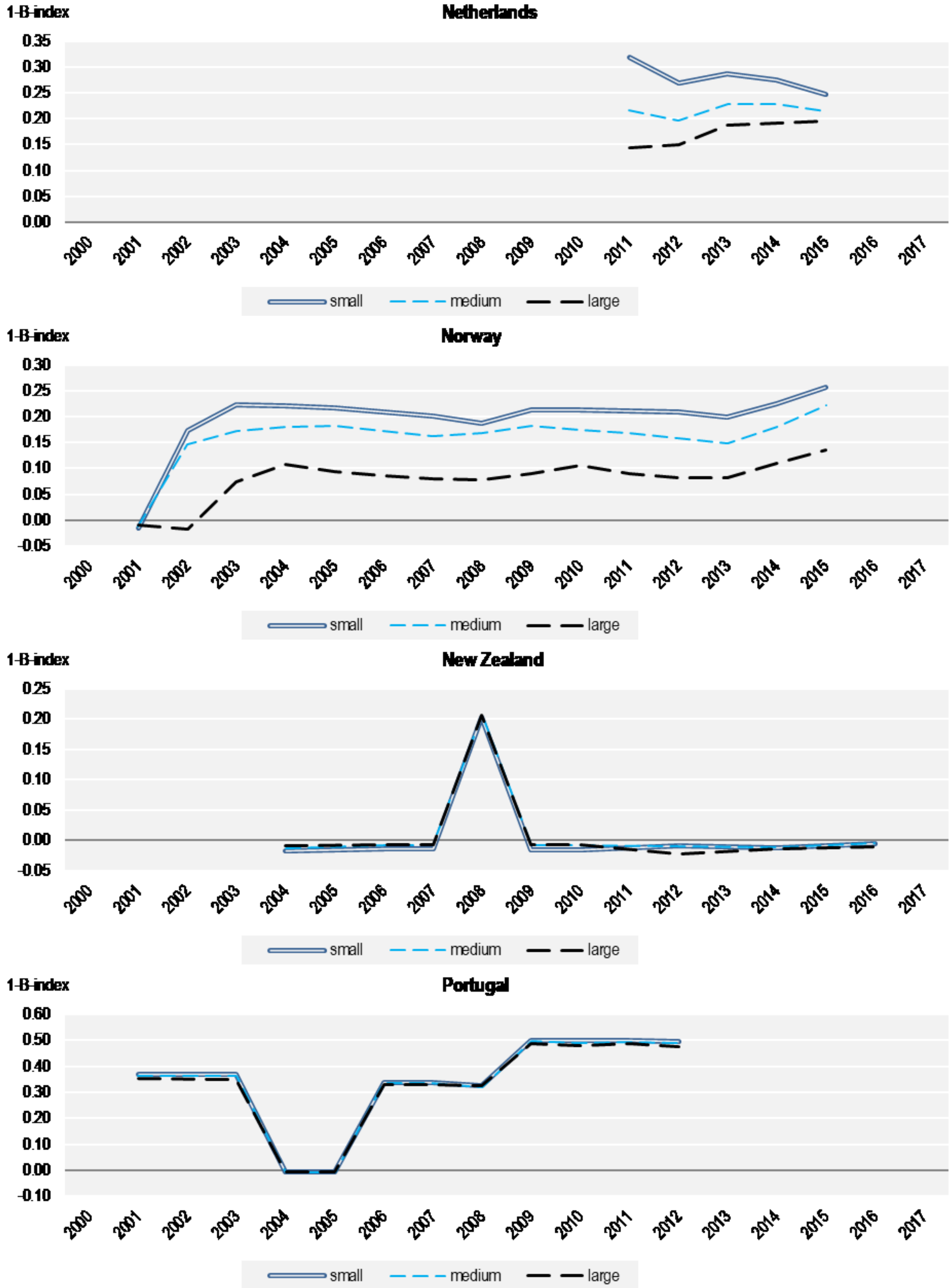
Figure A.1. Implied marg. R&D tax subsidy rates by firm size (profit scenario), 2000-2017

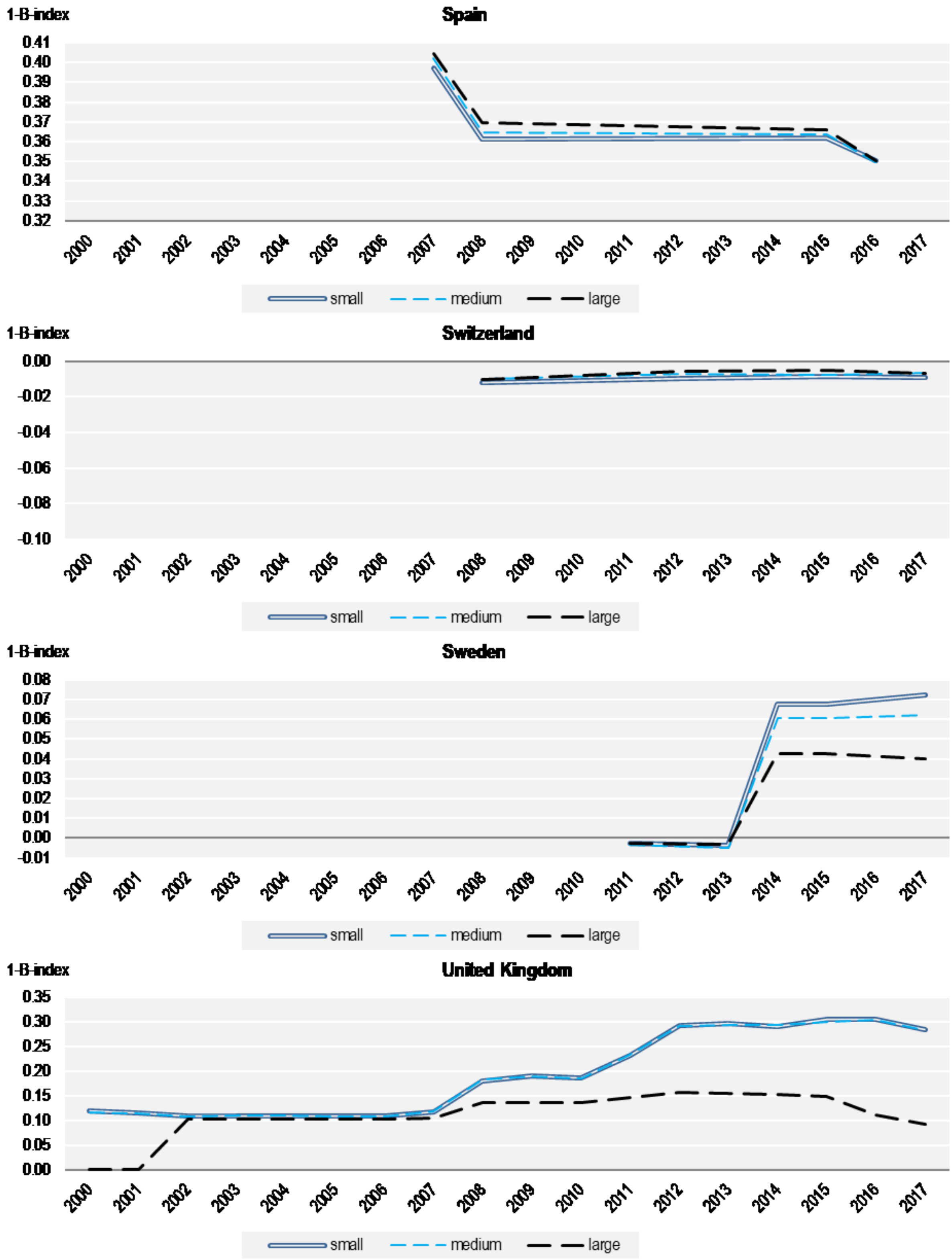
1-B-index, mean value estimated based on BERD microdata




1-B-index
Chile
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large
1-B-index
Czech Republic
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large
1-B-index
France
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large
1-B-index
Germany
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large


1-B-index
Hungary
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
All firms
1-B-index
Israel
0.00
-0.01
-0.02
-0.03
-0.04
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large
1-B-index
Italy
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.02
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large
1-B-index
Japan
0.25
0.20
0.15
0.10
0.05
0.00
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large

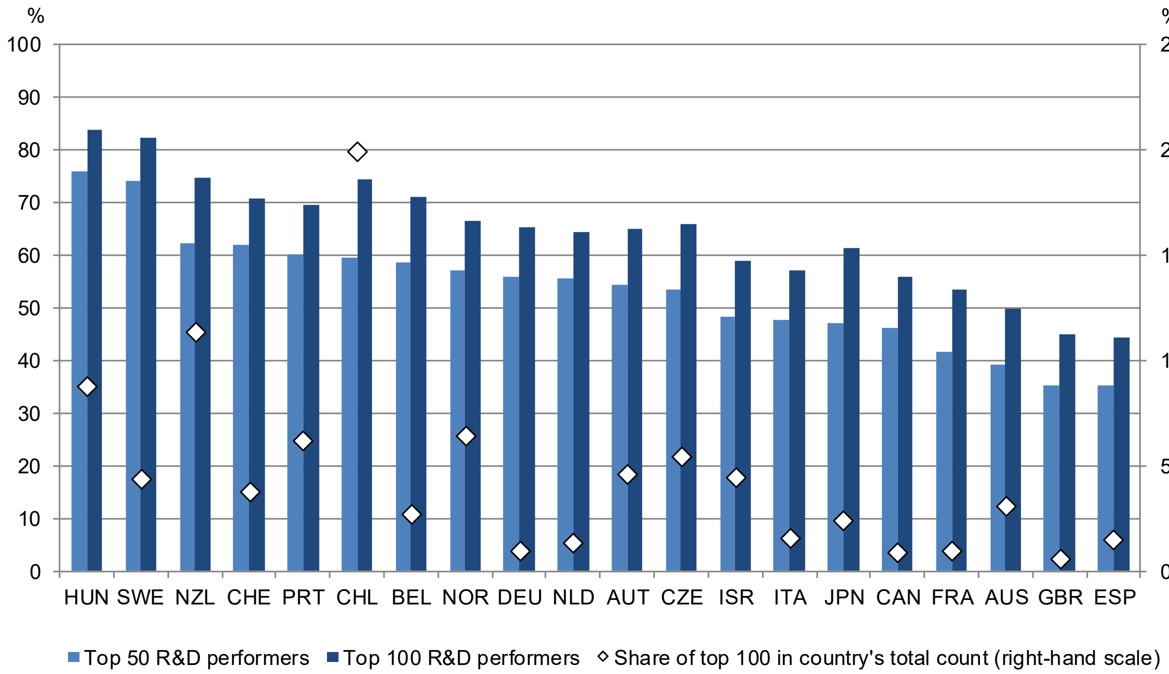

1-B-index
Netherlands
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large
1-B-index
Norway
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large
1-B-index
New Zealand
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large
1-B-index
Portugal
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017
small
medium
large



Note: The figure displays marginal R&D tax subsidy rates based on BERD microdata for the 20 OECD countries participating in the cross-country impact analysis. Subsidy rates are calculated separately for each firm. Values represent averages across all R&D performing firms in each country and year by firm size (small, medium, large), except for Hungary where they represent averages across all R&D performing firms.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Figure A.2. Concentration of business R&D: top 50 and top 100 performers, 2017 (or closest)

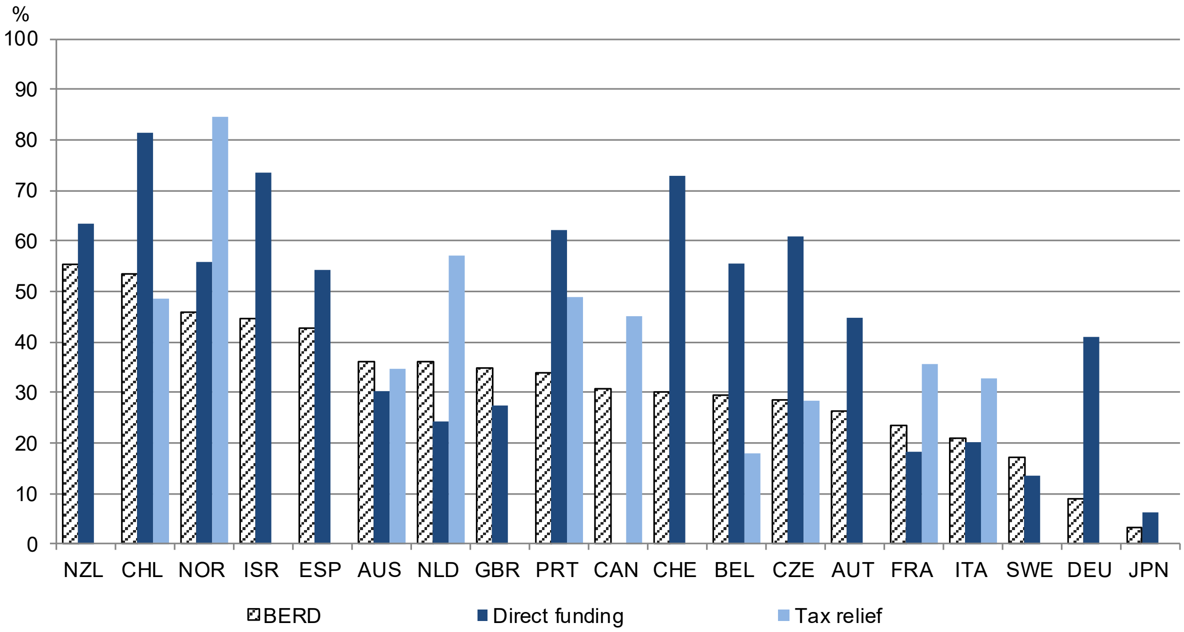
As percentage of domestic BERD or total count of performers



Note: JPN: unweighted, ISR: establishment level. The analysis covers enterprises with 10 or more employees except for Japan, where it covers enterprises with 50 or more employees. The analysis covers industry sectors (ISIC Rev.4, two-digit level) 5-72, excluding 45, 47, 55-56 and 68-69. Figures for Australia, Chile, the Czech Republic, Hungary, Israel, Japan, New Zealand, and Spain refer to 2016 instead of 2017. Figures for Austria, France, the Netherlands and Norway refer to 2015. Figures for Italy refer to 2014, those for Belgium, Canada and Germany to 2013, while those for Portugal refer to 2012.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Figure A.3. Share of BERD, direct and tax support accounted for by SMEs, 2017 (or closest)

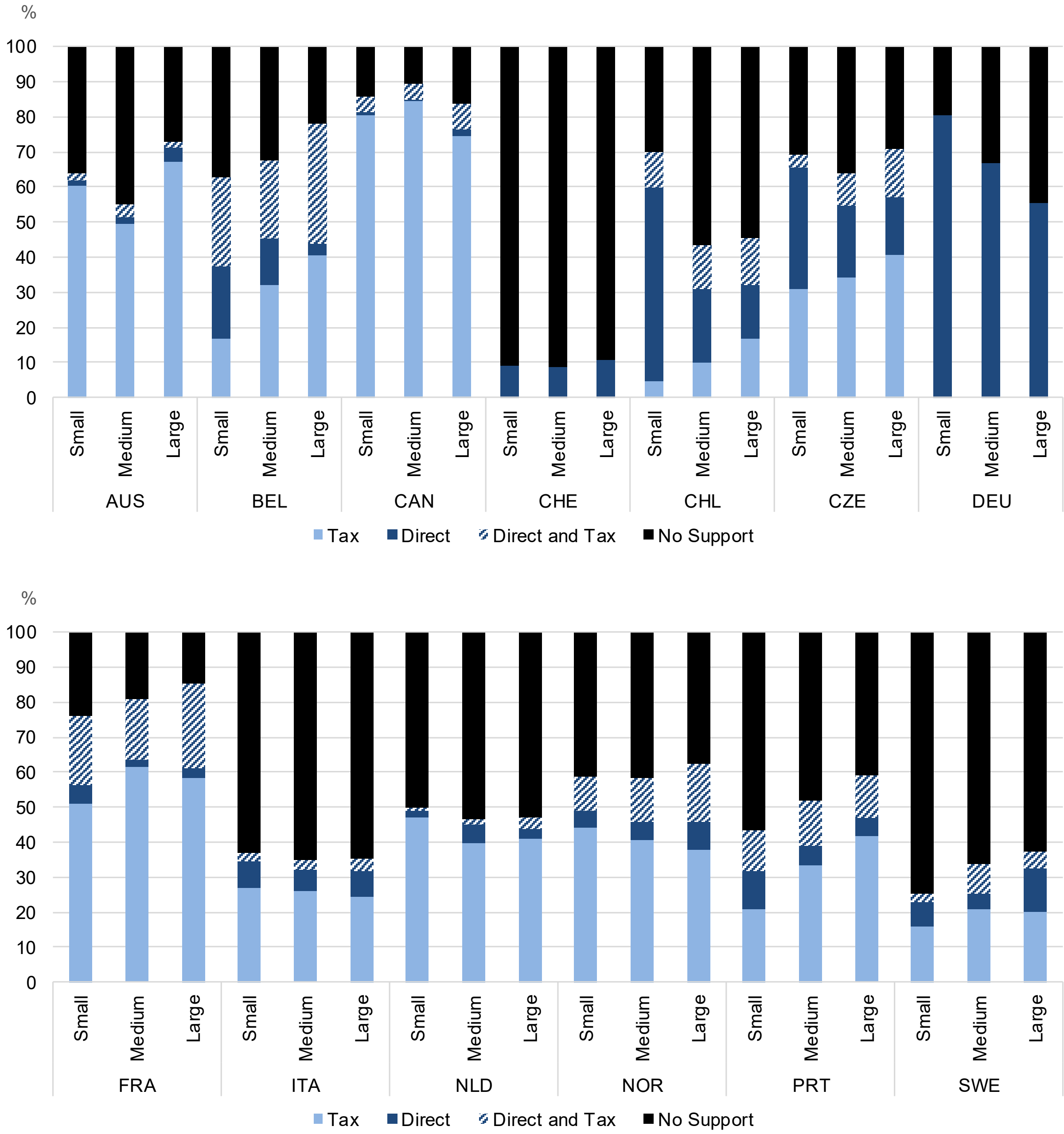
Percentage of domestic BERD, direct and tax support for BERD (BERD data sample)



Note: JPN: unweighted, ISR: establishment level. Micro-aggregated statistics on the SME share in tax support for BERD are calculated based on the matched BERD and tax relief sample and may thus deviate from official R&D tax relief statistics that are based on the whole population of R&D tax relief recipients. R&D tax support figures are not available for Austria, Chile, Spain, Israel, Japan, and New Zealand, and in the case of Chile, figures are based on all industries. Micro-aggregated statistics on the SME share in direct funding of BERD are not available for Canada. In the case of the Netherlands, official statistics on the SME share in BERD, direct funding of BERD and R&D tax support are reported instead of micro-aggregated statistics. Figures for Australia, Chile, the Czech Republic, Israel, Japan, New Zealand and Spain refer to 2016 instead of 2017, Figures for Austria, the Netherlands and Norway, refer to 2015. For France, figures refer to 2014, those for Belgium, Canada, and Germany refer to 2013, and those for Portugal and Italy to 2012 and 2009 respectively. The analysis covers industry sectors (ISIC Rev.4, two-digit level) 5-72, excluding 45, 47, 55-56 and 68-69.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Figure A.4. Direct and tax support recipients, 2017 (or closest)

As percentage of total number of R&D performers within each size category (BERD data sample)



Notes: Figures are presented for countries that offer no R&D tax incentives and those that do offer such support in 2017 (or closest year) and have access to R&D tax relief microdata. R&D performers are defined as firms with either positive intramural or extramural R&D expenditure. Applying a broader definition of R&D performers –both intramural and extramural R&D qualify for R&D tax support in many OECD countries –, figures may differ from national figures. Furthermore, micro-aggregated statistics on the share of R&D tax relief recipients are calculated based on the matched BERD and tax relief sample and may thus deviate from official R&D tax relief statistics that are based on the whole population of R&D tax relief recipients. Figures for Australia and the Czech Republic refer to 2016 instead of 2017, Figures for the Netherlands and Norway refer to 2015. Figures for France refer to 2014, for Belgium, Canada and Germany, they refer to 2013 and those for Portugal and Italy refer to 2012 and 2009 respectively. The analysis covers industry sectors (ISIC Rev.4, two-digit level) 5-72, excluding 45, 47, 55-56 and 68-69.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Annex B. R&D tax incentive design

Table B.1. Main R&D tax incentive design features, 2017 (or latest year)

R&D tax incentive provisions modelled in the microdata distributed impact analysis

	Main features of R&D tax incentive provisions					
Country	**Instrument**	**Qualifying R&D**	**Rates**	**Limitations of benefits**	**Preferential terms for SMEs/young firms**	**Treatment of excess claims (not modelled)**
Australia (2016)	R&D Tax Incentive (R&D tax credit)	Current, depreciation (machinery and equipment)	40 (45 if SME)	Floor and Ceiling (R&D expenditure)	Enhanced tax credit rates and refund provision	Indefinite carry-forward, refund for firms with a turnover less than AUD 20 million
Austria (2016)	R&D premium (R&D tax credit)	Current and capital	12	Ceiling (subcontracted R&D expenditure)	n.a.	Refund (or indefinite carry-forward)
Belgium (2015)	• Payroll withholding tax exemption • R&D tax allowance / tax credit (mutually exclusive)	• Labour • Machinery and equipment, buildings	• 80 • 13.5 / 3.99	• Payroll withholding tax liability (R&D tax benefits) • n.a. / n.a.	• Payroll withholding tax exemption: no Master qualification requirement for employees at young innovative firm • n.a. / n.a.	• Refund (redeemable against payroll withholding tax) • Indefinite carry-forward / refund after 4 years
Canada (2013)	SR&ED tax credit	Current	35 below CAD 3 million expenditure limit, 15 above	Threshold (R&D expenditure limit; reduced as a function of taxable income and taxable capital)	Exclusive refund provision for Canadian-controlled Private Corporations (CCPCs)	Refund (CCPC) 20 (carry-forward), 3 (carry-back)

Chile (2016)	R&D tax credit	Current and depreciation (machinery and equipment, buildings)	35 (26.6 net of tax)	Floor and Ceiling (eligible R&D expenditure)	n.a.	Indefinite carry-forward
Czech Republic (2016)	R&D tax allowance	Current and depreciation of movable fixed assets	100 (volume); 10 (increment above R&D spend in previous year)	n.a.	n.a.	3 (carry-forward)
France (2014)	R&D tax credit	Current, depreciation	30 below EUR 100 million, 5 above	Threshold (R&D expenditure)	SME exclusive refund provision	Immediate (SMEs); after 3 years if any remaining tax credit (large firms)
Germany (2013)	No R&D tax incentives (2000-17)					
Hungary (2016)	• R&D tax allowance • Social security (SSC) exemption	• Current, machinery and equipment, buildings • Labour	• 100 (300 if R&D collaboration) • 100 (SSC rate: 28.5% researchers, 14.5% PhDs)	• Ceiling (R&D collaboration) • Gross wages per month limited at HUF 500k (HUF 200k if PhD student)	n.a.	• 5 (carry-forward) • Refund (redeemable against social security contributions)
Israel (2016)	Accelerated depreciation	Machinery and equipment, buildings	2x (4x) standard rate for ME (BL)	Tax deduction (subcontracted R&D)	n.a.	Indefinite carry-forward
Italy (2014)	R&D tax credit (2007-2009)	Current, machinery and equipment	10	Ceiling (R&D expenditure)	n.a.	n.a.
Japan (2016)	R&D tax credits	Current and depreciation (machinery and equipment, buildings)	Volume: 10 (12 if SME) Increment: 5 (above average R&D spend in previous 3 years)	Ceiling (R&D tax benefits)	Enhanced R&D tax credit rate for SMEs (volume)	n.a.
Netherlands (2016)	WBSO (Payroll withholding tax credit)	Labour, machinery and equipment, intangibles, buildings	32 below EUR 350 000, 16 above	Payroll withholding tax liability (R&D tax benefits)	Refund (redeemable against payroll withholding tax)	Refund (redeemable against payroll withholding tax)
New Zealand (2016)	No R&D tax incentives (2000-07 and 2009-17; tax credit for deficit related R&D, introduced in 2015 not modelled, being applicable in loss making case only)					
Norway (2015)	Skattefunn (R&D tax credit)	Current, machinery and equipment	18 (20 if SME)	Ceiling (in-house, subcontracted and total R&D expenditure)	Enhanced R&D tax credit rate for SMEs	Refund (immediately in the following year)

Portugal (2012)	SIFIDEE II (R&D tax credit)	Current, machinery and equipment, intangibles	Volume: 32.5, 47.5 (if start-up); Increment: 50 (above average R&D spend in previous 2 fiscal years)	Increment: EUR 1.5 million (R&D expenditure)	Enhanced R&D tax credit rate for start-ups (volume)	8 (carry-forward)
Spain (2016)	R&D&I tax credit	Current, Machinery & Equipment (ME), intangibles	Volume: 25 (Current), =17 (R&D staff), 8 (M&E and intangibles) Increment: 17 (above average R&D spend in previous two years)	Ceiling (R&D tax benefits and refund)	Except for innovative SMEs, the R&D&I tax credit and SSC exemption are partially mutually exclusive in their use.	Refund (optional at 20% discount), 18 (carry-forward)
Sweden (2017)	Partial exemption of employer social security contributions	Labour	10	Ceiling (R&D tax benefits)	n.a.	Refund (Redeemable against employer social security contributions)
Switzerland (2017)	No R&D tax incentives (2000-17)					
United Kingdom (2017)	• R&D tax allowance (SMEs) • R&D tax credit (large firms)	Current	• 130 • 11	• Ceiling, R&D tax relief per project, subcontracted R&D) • N.a.	Enhanced rate of R&D tax relief (R&D tax allowance rate) for SMEs	Refund, indefinite carry-forward

Note: The year in parentheses marks the last year for which data is available for a given country. The treatment of excess claims has not been modelled. Subject to data availability, future OECD work (microBeRD+) aims to extend the analysis to the loss-making scenario and incorporate such provisions in the modelling of marginal R&D tax subsidy rates. For more detailed information on the design of R&D tax incentives in OECD countries and partner economies, see http://www.oecd.org/sti/rd-tax-stats-compendium.pdf and http://www.oecd.org/sti/rd-tax-stats.htm#countries

Source: OECD R&D Tax Incentives database, http://oe.cd/rdtax, June 2020.

Annex C. Cross-country analysis: additional results

Table C.1. R&D price elasticity - non-linearity of effects

Baseline specification

Sample	Full	2-year lags of R&D
Dependent variable:	Intramural	Intramural
log R&D expenditure	(1)	(2)
log BIndex	-0.538***	
	(0.183)	
log BIndex squared	0.051	
	(0.263)	
log BIndexSyn		-0.714***
		(0.140)
log BIndexSyn squared		-0.075
		(0.193)
Observations	9679	6822
Countries	20	18

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-industry-size class level. All regressions control for industry-level log value added lagged by two years, country-industry-size class fixed effects, industry-year fixed effects and size class-year fixed effects. The full sample covers 20 OECD countries: Australia, Austria, Belgium, Canada, Chile, the Czech Republic, France, Germany, Hungary, Israel, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Results in column 2 are based on observations with non-missing values of BIndexSyn and do not include Spain and Switzerland.

Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Table C.2. R&D price elasticity by firm size and age

Micro-aggregated data at country, macro industry, firm size and age level

Dependent variable:	**Intramural**		
log R&D expenditure	(1)	(2)	(3)
log BIndex	-0.360	-0.572**	-0.170
	(0.365)	(0.279)	(0.407)
log BIndex x medium	-0.240		-0.175
	(0.490)		(0.460)
log BIndex x small	-1.046**		-0.942*
	(0.491)		(0.519)
log BIndex x young		-0.705*	-0.604
		(0.376)	(0.387)
Country-industry-size class FE	Y	Y	Y
Industry -Year FE	Y	Y	Y
Size class – Year FE	Y	Y	Y
Age class – Year FE	Y	Y	Y
Observations	837	837	837
Countries	10	10	10

Note: *** 1%, ** 5%, * 10%. Standard errors in parentheses are clustered at the country-macro industry-size class-age class level. Observations are defined at the country-macro industry-size class-age class level. All regressions control for country-industry-size class fixed effects, industry-year fixed effects, size class-year fixed effects and age class year-fixed effects. Small firms are defined as firms with 10-49 employees and medium firms as firms with 50-249 employees. Young firms are defined as firms with less than 5 years of age. The analysis covers 10 OECD countries: Australia, Belgium, Chile, the Czech Republic, Israel, New Zealand, Norway, Portugal, Spain and Sweden.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Annex D. Firm-level analysis: additional results

Table D.1. Effects of R&D tax incentives by type of cost and orientation of R&D

R&D tax relief beneficiaries vs. non-beneficiaries

Dependent var.: log R&D	Intramural	Labour	Other current	Capital	Extramural	R&D emp.	R&D wages	Research	Develop ment
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					Australia				
ATT (*not comparable*	0.135**	0.058	0.373***	0.147		0.05	0.008	0.027	0.167*
across countries)	(0.059)	(0.049)	(0.098)	(0.163)		(0.055)	(0.031)	(0.091)	(0.093)
Observations	7678	7651	7227	4298		7651	7651	4735	6123
Implied elasticity	-0.90	-0.39	-2.50	-0.99		-0.34	-0.05	-0.18	-1.12
					Belgium				
ATT (*not comparable*	0.304***	0.362***	0.169	0.039	0.229	0.183**	0.188***	0.087	0.259**
across countries)	(0.094)	(0.089)	(0.145)	(0.15)	(0.202)	(0.076)	(0.064)	(0.12)	(0.111)
Observations	1474	1361	1190	898	679	1470	1357	1199	1108
Implied elasticity	-1.79	-2.13	-1.00	-0.23	-1.35	-1.08	-1.11	-0.51	-1.53
					Chile (DID based on policy change)				
ATT (*not comparable*	0.103	0.067	0.317	-0.007	-0.393	0.160	-0.086	0.271*	-0.072
across countries)	(0.136)	(0.138)	(0.247)	(0.245)	(0.785)	(0.104)	(0.121)	(0.158)	(0.218)
Observations	2056	2048	1510	1129	336	2052	2048	1467	1385
Implied elasticity	-0.33	-0.21	-1.01	0.02	1.25	-0.51	0.27	-0.86	0.23
					Czech Republic				
ATT (*not comparable*	0.161***	0.117***	0.288***	0.297*	0.331*	0.137***	-0.021	0.162*	0.1
across countries)	(0.046)	(0.04)	(0.087	(0.17)	(0.192)	(0.039)	(0.03)	(0.083)	(0.075)
Observations	6017	6016	5952	2347	1697	6016	6016	2972	4139
Implied elasticity	-0.63	-0.46	-1.13	-1.17	-1.30	-0.54	0.08	-0.64	-0.39
					France				
ATT (*not comparable*	0.082***	0.059**	0.099**	0.071	0.045	0.078***	-0.019	0.036	0.111**
across countries)	(0.024)	(0.023)	(0.041	(0.099)	(0.083)	(0.02)	(0.015)	(0.044)	(0.044)
Observations	6673	6672	6193	3875	3426	6670	6669	5576	4720
Implied elasticity	-0.17	-0.12	-0.21	-0.15	-0.09	-0.16	0.04	-0.08	-0.23
					Italy				
ATT (*not comparable*	-0.038	-0.023	0.001	-0.139	-0.079	-0.070**	0.045**	0.018	-0.066
across countries)	(0.027)	(0.029)	(0.060)	(0.132)	(0.123)	(0.029)	(0.023)	(0.048)	(0.043)
Observations	18009	17896	11929	5827	5288	18009	17896	12222	11305
Implied elasticity	-0.24	-0.15	0.01	-0.89	-0.51	-0.45	0.29	0.12	-0.42
					Japan (DID based on policy change)				
ATT (*not comparable*	0.056***	0.057***	0.02	0.199***	0.104	0.019	0.017	0.037	-0.055
across countries)	(0.019)	(0.018)	(0.029	(0.068)	(0.076)	(0.043)	(0.022)	(0.063)	(0.042)
Observations	20805	20697	20637	13026	8581	9154	9152	4443	8828
Implied elasticity	-0.52	-0.53	-0.19	-1.86	-0.97	-0.18	-0.16	-0.35	0.51

					Norway				
ATT (*not comparable*	0.337***	0.240***	0.276***	0.344*	0.088	0.241**	-0.014	0.411**	0.253**
across countries)	(0.061)	(0.057)	(0.094)	(0.185)	(0.182)	(0.1)	(0.082)	(0.176)	(0.099)
Observations	2420	2419	2052	1169	1367	1395	1395	644	1225
Implied elasticity	-2.70	-1.92	-2.21	-2.75	-0.70	-1.93	0.11	-3.29	-2.02
					Portugal				
ATT (*not comparable*	0.752***	0.587***	0.949***	0.620*	-0.322	0.496***	0.091	0.729***	0.772***
across countries)	(0.115)	(0.094)	(0.22)	(0.346)	(0.324)	(0.089)	(0.079)	(0.181)	(0.132)
Observations	2014	2014	1259	852	583	2014	2014	989	1792
Implied elasticity	-1.15	-0.90	-1.46	-0.95	0.49	-0.76	-0.14	-1.12	-1.18
					Sweden				
ATT (*not comparable*	0.116*	0.094	0.097	-0.233	0.104	0.136**	-0.038	0.103	0.079
across countries)	(0.065)	(0.065)	(0.12)	(0.181)	(0.266)	(0.069)	(0.053)	(0.145)	(0.084)
Observations	1618	1607	1552	951	796	1606	1598	900	1551
Implied elasticity	-2.51	-2.03	-2.10	5.04	-2.25	-2.94	0.82	-2.23	-1.71

Note: *** 1%, ** 5%, * 10%. All regressions control for firm sales (employment if sales not available), firm fixed effects and year fixed effects. R&D employment and R&D wages (implied R&D unit labour costs) are measured in full-time equivalents except for Japan, where headcounts are used. Estimates are based on policy uptake, except for Japan (based on policy change). The estimates for Chile, Italy and Japan are based on a policy change.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.

Table D.2. Effects of R&D direct support by type of cost and orientation of R&D

Direct support recipients vs. non-recipients

Dependent var.: log R&D	Intramural	Labour	Other current	Capital	Extramural	R&D emp.	R&D wages	Research	Development
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
					Austria				
ATT (*not comparable*	0.372***	0.294***	0.386***	0.251*	0.060	0.264***	0.032	0.248***	0.470***
across countries)	(0.049)	(0.048)	(0.075)	(0.136)	(0.119)	(0.047)	(0.024)	(0.073)	(0.068)
Observations	8146	8143	7570	3905	2724	8146	8143	5539	6938
					Canada				
ATT (*not comparable*	0.311***	0.264***	0.399***	0.203**	0.367***				
across countries)	(0.036)	(0.034)	(0.078)	(0.098)	(0.093)				
Observations	113650	113560	80760	32630	57350				
					Czech Republic				
ATT (*not comparable*	0.428***	0.325***	0.742***	0.518**	0.439	0.269***	0.045	0.438***	0.339***
across countries)	(0.059)	(0.062)	(0.107)	(0.219)	(0.284)	(0.056)	(0.039)	(0.115)	(0.081)
Observations	8134	8026	7765	3177	925	8134	8026	3153	5790
					Germany				
ATT (*not comparable*	0.095***	0.111***	0.159***	0.084**	0.074*	0.094***	0.016	0.109***	0.097***
across countries)	(0.018)	(0.019)	(0.027)	(0.034)	(0.040)	(0.018)	(0.012)	(0.022)	(0.031)
Observations	43038	43001	41821	30259	15989	43003	43001	41013	26006
					France				
ATT (*not comparable*	0.134***	0.121***	0.121**	0.198**	-0.004	0.123***	-0.002	0.124**	0.092*
across countries)	(0.027)	(0.026)	(0.055)	(0.088)	(0.093)	(0.026)	(0.017)	(0.051)	(0.049)
Observations	26025	26013	23835	14226	13438	26017	26005	20384	18310
					Italy				

Dependent var.: log R&D	Intramural	Labour	Other current	Capital	Extramural	R&D emp.	R&D wages	Research	Development
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ATT (*not comparable across countries*)	0.186***	0.154***	0.070	0.135	-0.067	0.118***	0.038	0.194**	0.092
	(0.050)	(0.053)	(0.101)	(0.119)	(0.149)	(0.043)	(0.036)	(0.089)	(0.099)
Observations	27049	26979	17376	8409	6527	27049	26979	19225	17081
Japan									
ATT (*not comparable across countries*)	0.114***	0.056***	0.155***	0.208***	0.168**	0.061***	-0.005	0.113***	0.076***
	(0.017)	(0.015)	(0.026)	(0.055)	(0.071)	(0.013)	(0.015)	(0.035)	(0.023)
Observations	172444	171131	171519	122698	63441	172370	171063	78700	166719
Norway									
ATT (*not comparable across countries*)	0.470***	0.343***	0.591***	0.468*	0.503***	0.068	0.050	0.185	0.537***
	(0.083)	(0.079)	(0.124)	(0.249)	(0.194)	(0.080)	(0.067)	(0.189)	(0.103)
Observations	4211	4210	3366	2023	1777	2911	2911	1215	2393
New Zealand									
ATT (*not comparable across countries*)	0.517***	0.581***	0.522***	-0.166	0.437	0.496***	0.103	0.520**	0.255
	(0.124)	(0.117)	(0.201)	(0.325)	(0.453)	(0.143)	(0.131)	(0.245)	(0.178
Observations	789	768	714	363	117	753	738	519	693
Portugal									
ATT (*not comparable across countries*)	0.224**	0.217**	0.269**	-0.064	0.100	0.253***	-0.034	0.163	0.202*
	(0.098)	(0.088)	(0.134)	(0.310)	(0.215)	(0.087)	(0.064)	(0.183)	(0.110)
Observations	3714	3714	2971	1822	1062	3713	3713	1977	3343

Note: *** 1%, ** 5%, * 10%. All regressions control for firm sales (employment if sales not available), firm fixed effects and year fixed effects. R&D employment and R&D wages (implied R&D unit labour costs) are measured in full-time equivalents except for Japan, where headcounts are used.
Source: OECD microBeRD project, http://oe.cd/microberd, June 2020.